OPSAWG
Internet-Draft
Intended status: Standards Track
Expires: April 16, 2014

H. Asai
Univ. of Tokyo
M. MacFaden
VMware Inc.
J. Schoenwaelder
Jacobs University
Y. Sekiya
Univ. of Tokyo
K. Shima
IIJ Innovation Institute Inc.
T. Tsou
Huawei Technologies (USA)
C. Zhou
Huawei Technologies
H. Esaki
Univ. of Tokyo

October 13, 2013

Management Information Base for Virtual Machines Controlled by a Hypervisor
draft-asai-vmm-mib-05

Abstract

This document defines a portion of the Management Information Base (MIB) for use with network management protocols in the Internet community. In particular, this specifies objects for managing virtual machines controlled by a hypervisor (a.k.a. virtual machine monitor).

Status of this Memo

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

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at http://datatracker.ietf.org/drafts/current/.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

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

Copyright Notice

Table of Contents

1. Introduction

This document defines a portion of the Management Information Base (MIB) for use with network management protocols in the Internet community. In particular, this specifies objects for managing virtual machines controlled by a hypervisor (a.k.a. virtual machine monitor). A hypervisor controls multiple virtual machines on a single physical machine by allocating resources to each virtual machine using virtualization technologies. Therefore, this MIB module contains information on virtual machines and their resources controlled by a hypervisor as well as hypervisor’s hardware and software information.

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

1.1. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

2. The Internet-Standard Management Framework

For a detailed overview of the documents that describe the current Internet-Standard Management Framework, please refer to section 7 of RFC 3410 [RFC3410]. Managed objects are accessed via a virtual information store, termed the Management Information Base or MIB. MIB objects are generally accessed through the Simple Network Management Protocol (SNMP). Objects in the MIB are defined using the mechanisms defined in the Structure of Management Information (SMI). This memo specifies a MIB module that is compliant to the SMIv2, which is described in STD 58, RFC 2578 [RFC2578], STD 58, RFC 2579 [RFC2579] and STD 58, RFC 2580 [RFC2580].

3. Managed Objects for Virtual Machines Controlled by a Hypervisor

3.1. Managed Objects on Virtualization Environment

On the common implementations of hypervisor softwares, a hypervisor allocates virtual resources such as virtual CPUs, virtual memory, virtual storage devices, and virtual network interfaces to virtual machines from physical resources. This document defines objects related to system and software information of a hypervisor, the list of virtual machines controlled by the hypervisor, and virtual resources allocated by the hypervisor to virtual machines. This document specifies four specific types of virtual resources that are common to general hypervisors; CPUs (processors), memory, network interfaces, and storage devices.

```
    +------------------------------------------------------------------+
    | +-------------------------------------------+                    |
    | | Virtual machine                           |                    |
    | |                                           |                    |
    | | +---------+ +---------+ +---------+       | .........          |
    | | | Virtual | | Virtual | | Virtual |       |                    |
    | +-| CPU     |-| memory  |-| storage |... ---+                    |
    |   +---------+ +---------+ +---------+                            |
    |            Virtual resources                                     |
    |                   ^                                              |
    |                   | Allocation using virtualization technologies |
    |                   |                                              |
    |                   +---------- Physical resources   ._____.       |
    |                       +--------+    .--------.    /       \      |
    |  +==============+     |        |   /________/|   *\_______/*     |
    +- || SNMP agent || - - |  CPU   | - | Memory |/ - | Storage | .. -+
    |  +==============+     +--------+   +--------+     \_______/      |
    | Hypervisor                                                       |
    +------------------------------------------------------------------+
```

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

Figure 1: An example of a virtualization environment

As shown in Figure 1, the objects defined in this document are managed at a hypervisor and an SNMP agent is launched at the hypervisor to provide access to the objects. The objects are managed from the viewpoint of the operators of hypervisors, but not the operators of virtual machines; i.e., the objects do not take into account the actual resource utilization on each virtual machine but the resource allocation from the physical resources. For example, vmNetworIfIndex indicates the virtual interface associated with an interface of a virtual machine at the hypervisor, and consequently, the ‘in’ and ‘out’ directions denote ‘from a virtual machine to the hypervisor’ and ‘from the hypervisor to a virtual machine’, respectively. Moreover, vmStorageAllocatedSize denotes the size allocated by the hypervisor, but not the size actually used by the operating system on the virtual machine. This means that vmStorageDefinedSize and vmStorageAllocatedSize do not take different values when the vmStorageSourceType is ‘block’ or ‘raw’.

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

3.2. Overview of the MIB Module

The MIB module is organized into a group of scalars and tables. The scalars below ‘hypervisor’ provide basic information about the hypervisor. The ‘vmTable’ lists the virtual machines (guests) that are known to the hypervisor. The ‘vmCpuTable’ provides the mapping table of virtual CPUs to virtual machines, including CPU time used by each virtual CPU. The ’vmCpuAffinityTable’ provides the affinity of each virtual CPU to a physical CPU. The ‘vmStorageTable’ provides the list of virtual storage devices and their mapping to virtual machines. In case that an entry in the ‘vmStorageTable’ has a corresponding parent physical storage device managed in ‘hrStorageTable’ of HOST-RESOURCES-MIB [RFC2790], the entry contains a pointer ‘vmStorageParent’ to the physical storage device. The ‘vmNetworkTable’ provides the list of virtual network interfaces and their mapping to virtual machines. Each entry in the ‘vmNetworkTable’ also provides a pointer ‘vmNetworIfIndex’ to the corresponding entry in the ‘ifTable’ of IF-MIB [RFC2863]. In case that an entry in the ‘vmNetworkTable’ has a corresponding parent physical network interface managed in ‘ifTable’ of IF-MIB, the entry contains a pointer ‘vmNetworkParent’ to the physical network interface.

```
    *: ‘vmAdminState’ write access
    !: Notification
    +-------------+   + - - - - - - +
    | finite      |   | transient   |
    | vmOperState |   | vmOperState |
    +-------------+   + - - - - - - +

    ================================================================

    +--------------+   + - - - - - - - +     +-------------+
    |  suspended   |<--|  suspending   |     |   paused     |
    | !vmSuspended |   | !vmSuspending |     |  !vmPaused   |
    +--------------+   + - - - - - - - +     +-------------+
          |                ^ *suspended         ^ *paused
          |                |                    |
          v  *running      |         *running   |
    + - - - - - - +   +-------------+<----------+    + - - - - - - -+
    |  resuming   |-->|   running   |<-------------->|  migrating   |
    | !vmResuming |   |  !vmRunning |                | !vmMigrating |
    + - - - - - - +   +-------------+                + - - - - - - -+
                           |      ^ *running                ^
                           |      |                         |
                           |      +-------------------+    |
                           |                          |    |
                           v *shutdown       *destroy v    v
                    + - - - - - - - - +          +-------------+
                    |  shuttingdown   |---------->|  shutdown   |
                    | !vmShuttingdown |          | !vmShutdown |
                    + - - - - - - - - +          +-------------+
                                                     ^      |
                                                     |      v !vmDeleted
    + - - - - - -+   +------------+     + - - - - - - +    (Deleted from
    |  blocked   |   |  crashed   |     |  preparing  |     vmTable)
    | !vmBlocked |   | !vmCrashed |     |             |
    + - - - - - -+   +------------+     + - - - - - - +
```

The state transition of a virtual machine

Figure 2: State transition of a virtual machine

The ‘vmAdminState’ and ‘vmOperState’ textual conventions define an administrative state and an operational state model for virtual machines. Events causing transitions between major operational states will cause the generation of notifications. Per virtual machine (per-VM) notifications (vmRunning, vmShutdown, vmPaused, vmSuspended, vmCrashed, vmDeleted) are generated if vmPerVMNotificationsEnabled is true(1). Bulk notifications (vmBulkRunning, vmBulkShutdown, vmBulkPaused, vmBulkSuspended, vmBulkCrashed, vmBulkDeleted) are generated if vmBulkNotificationsEnabled is true(1). The transition of ‘vmOperState’ by the write access to ‘vmAdminState’ and the notifications generated by the operational state changes are summarized in Figure 2. Note that the notifications shown in this figure are per-VM notifications. In the case of Bulk notifications, the prefix ‘vm’ is replaced with ’vmBulk’.

The bulk notification mechanism is designed to reduce the number of notifications that are trapped by an SNMP manager. This is because the number of virtual machines managed by a bunch of hypervisors in a datacenter possibly becomes several thousands or more, and consequently, many notifications could be trapped if these virtual machines frequently change their administrative state. The per-VM notifications carry more detailed information, but the scalability shall be a problem. An implementation shall support both, either of, or none of per-VM notifications and bulk notifications. The notification filtering mechanism described in section 6 of RFC 3413 [RFC3413] is used by the management applications to control the notifications.

The MIB module provides a few writable objects that can be used to make non-persistent changes, e.g., changing the memory allocation or the CPU allocation. It is not the goal of this MIB module to provide a configuration interface for virtual machines since other protocols and data modeling languages are more suitable for this task.

The OID tree structure of the MIB module is shown below.

```
--vmMIB (1.3.6.1.2.1.yyy)
  +--vmNotifications(0)
  |  +--vmRunning(1) [vmName, vmUUID, vmOperState]
  |  +--vmShuttingdown(2) [vmName, vmUUID, vmOperState]
  |  +--vmShutdown(3) [vmName, vmUUID, vmOperState]
  |  +--vmPaused(4) [vmName, vmUUID, vmOperState]
  |  +--vmSuspending(5) [vmName, vmUUID, vmOperState]
  |  +--vmSuspended(6) [vmName, vmUUID, vmOperState]
  |  +--vmResuming(7) [vmName, vmUUID, vmOperState]
  |  +--vmMigrating(8) [vmName, vmUUID, vmOperState]
  |  +--vmCrashed(9) [vmName, vmUUID, vmOperState]
  |  +--vmBlocked(10) [vmName, vmUUID, vmOperState]
  |  +--vmDeleted(11) [vmName, vmUUID, vmOperState, vmPersistent]
  |  +--vmBulkRunning(12) [vmAffectedVMs]
  |  +--vmBulkShutdown(13) [vmAffectedVMs]
  |  +--vmBulkShuttingdown(14) [vmAffectedVMs]
  |  +--vmBulkPaused(15) [vmAffectedVMs]
  |  +--vmBulkSuspending(16) [vmAffectedVMs]
  |  +--vmBulkSuspended(17) [vmAffectedVMs]
```

```
     |  +--vmBulkResuming(18) [vmName, vmUUID, vmOperState]
     |  +--vmBulkMigrating(19) [vmAffectedVMs]
     |  +--vmBulkCrashed(20) [vmAffectedVMs]
     |  +--vmBulkBlocked(21) [vmAffectedVMs]
     |  +--vmBulkDeleted(22) [vmAffectedVMs]
     +--vmObjects(1)
     |  +--vmHypervisor(1)
     |  |  +-- r-n SnmpAdminString    vmHvSoftware(1)
     |  |  +-- r-n SnmpAdminString    vmHvVersion(2)
     |  |  +-- r-n OBJECT IDENTIFIER  vmHvObjectID(3)
     |  |  +-- r-n TimeTicks          vmHvUpTime(4)
     |  +-- r-n Integer32  vmNumber(2)
     |  +-- r-n TimeTicks  vmTableLastChange(3)
     |  +--vmTable(4)
     |  |  +--vmEntry(1) [vmIndex]
     |  |     +-- --- VirtualMachineIndex  vmIndex(1)
     |  |     +-- r-n SnmpAdminString      vmName(2)
     |  |     +-- r-n UUIDorZero           vmUUID(3)
     |  |     +-- r-n SnmpAdminString      vmOSType(4)
     |  |     +-- rwn VirtualMachineAdminState
     |  |     |                            vmAdminState(5)
     |  |     +-- r-n VirtualMachineOperState
     |  |     |                            vmOperState(6)
     |  |     +-- r-n VirtualMachineAutoStart
     |  |     |                            vmAutoStart(7)
     |  |     +-- r-n VirtualMachinePersistent
     |  |     |                            vmPersistent(8)
     |  |     +-- rwn Integer32            vmCurCpuNumber(9)
     |  |     +-- rwn Integer32            vmMinCpuNumber(10)
     |  |     +-- rwn Integer32            vmMaxCpuNumber(11)
     |  |     +-- r-n Integer32            vmMemUnit(12)
     |  |     +-- rwn Integer32            vmCurMem(13)
     |  |     +-- rwn Integer32            vmMinMem(14)
     |  |     +-- rwn Integer32            vmMaxMem(15)
     |  |     +-- r-n TimeTicks            vmUpTime(16)
     |  |     +-- r-n Counter64            vmCpuTime(17)
     |  +--vmCpuTable(5)
     |  |  +--vmCpuEntry(1) [vmIndex, vmCpuIndex]
     |  |     +-- --- VirtualMachineCpuIndex
     |  |     |                            vmCpuIndex(1)
     |  |     +-- r-n Counter64            vmCpuCoreTime(2)
     |  +--vmCpuAffinityTable(6)
     |  |  +--vmCpuAffinityEntry(1) [vmIndex,
     |  |     |                      vmCpuIndex,
     |  |     |                      vmCpuPhysIndex]
     |  |     +-- --- Integer32            vmCpuPhysIndex(1)
     |  |     +-- rwn Integer32            vmCpuAffinity(2)
     |  +--vmStorageTable(7)
     |  |  +--vmStorageEntry(1) [vmStorageVmIndex, vmStorageIndex]
     |  |     +-- --- VirtualMachineIndexOrZero
     |  |     |                            vmStorageVmIndex(1)
     |  |     +-- --- VirtualMachineStorageIndex
     |  |     |                            vmStorageIndex(2)
     |  |     +-- r-n Integer32            vmStorageParent(3)
     |  |     +-- r-n VirtualMachineStorageSourceType
     |  |     |                            vmStorageSourceType(4)
     |  |     +-- r-n SnmpAdminString      vmStorageSourceTypeString(5)
     |  |     +-- r-n SnmpAdminString      vmStorageResourceID(6)
     |  |     +-- r-n VirtualMachineStorageAccess
     |  |     |                            vmStorageAccess(7)
     |  |     +-- r-n VirtualMachineStorageMediaType
     |  |     |                            vmStorageMediaType(8)
     |  |     +-- r-n SnmpAdminString      vmStorageMediaTypeString(9)
     |  |     +-- r-n Integer32            vmStorageSizeUnit(10)
     |  |     +-- r-n Integer32            vmStorageDefinedSize(11)
     |  |     +-- r-n Integer32            vmStorageAllocatedSize(12)
     |  |     +-- r-n Counter64            vmStorageReadIOs(13)
     |  |     +-- r-n Counter64            vmStorageWriteIOs(14)
     |  +--vmNetworkTable(8)
     |  |  +--vmNetworkEntry(1) [vmIndex, vmNetworkIndex]
     |  |     +-- --- VirtualMachineNetworkIndex
     |  |     |                            vmNetworkIndex(1)
     |  |     +-- r-n InterfaceIndexOrZero vmNetworIfIndex(2)
     |  |     +-- r-n InterfaceIndexOrZero vmNetworkParent(3)
     |  |     +-- r-n SnmpAdminString      vmNetworkModel(4)
     |  |     +-- r-n PhysAddress          vmNetworkPhysAddress(5)
     |  +-- rwn TruthValue           vmPerVMNotificationsEnabled(9)
     |  +-- rwn TruthValue           vmBulkNotificationsEnabled(10)
     |  +-- --n VirtualMachineList   vmAffectedVMs(11)
     +--vmConformance(2)
        +--vmCompliances(1)
        |  +--vmFullCompliances(1)
        |  +--vmReadOnlyCompliances(2)
        +--vmGroups(2)
           +--vmHypervisorGroup(1)
           +--vmVirtualMachineGroup(2)
           +--vmCpuGroup(3)
           +--vmCpuAffinityGroup(4)
           +--vmStorageGroup(5)
           +--vmNetworkGroup(6)
           +--vmPerVMNotificationOptionalGroup(7)
           +--vmBulkNotificationsVariablesGroup(8)
           +--vmBulkNotificationOptionalGroup(9)
```

3.3. Definitions

```
   VM-MIB DEFINITIONS ::= BEGIN

   IMPORTS
       MODULE-IDENTITY, OBJECT-TYPE, NOTIFICATION-TYPE, TimeTicks,
       Counter64, Integer32, mib-2
           FROM SNMPv2-SMI
       OBJECT-GROUP, MODULE-COMPLIANCE, NOTIFICATION-GROUP
           FROM SNMPv2-CONF
       TEXTUAL-CONVENTION, PhysAddress, TruthValue
           FROM SNMPv2-TC
       SnmpAdminString
           FROM SNMP-FRAMEWORK-MIB
       UUIDorZero
           FROM UUID-TC-MIB
       InterfaceIndexOrZero
           FROM IF-MIB;

   vmMIB MODULE-IDENTITY
       LAST-UPDATED "201310130000Z"        -- 13 October 2013
       ORGANIZATION "IETF Operations and Management Area Working Group"
       CONTACT-INFO
               "
               WG E-mail: (To be added after approved by WG)
               Mailing list subscription info:
                 http:// (To be added after approved by WG)

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

               Yuji Sekiya
               The University of Tokyo
               2-11-16 Yayoi
               Bunkyo-ku, Tokyo  113-8658
               JP
               Email: sekiya@wide.ad.jp

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

               Tina Tsou
               Huawei Technologies (USA)
               2330 Central Expressway
               Santa Clara  CA 95050
               USA
               Email: tina.tsou.zouting@huawei.com

               Cathy Zhou
               Huawei Technologies
               Bantian, Longgang District
               Shenzhen  518129
               P.R. China
               Email: cathyzhou@huawei.com

               Hiroshi Esaki
               The University of Tokyo
               7-3-1 Hongo
               Bunkyo-ku, Tokyo  113-8656
               JP
               Email: hiroshi@wide.ad.jp
               "

       DESCRIPTION
               "This MIB module is for use in managing a hypervisor and
               virtual machines controlled by the hypervisor.  The OID
               ‘yyy’ is temporary one, and it must be assigned by IANA
               when this becomes an official document.

               Copyright (c) 2013 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 "201310130000Z"        -- 13 October 2013
       DESCRIPTION
               "The original version of this MIB, published as
               RFCXXXX."
       ::= { mib-2 yyy }


   vmNotifications OBJECT IDENTIFIER ::= { vmMIB 0 }
   vmObjects       OBJECT IDENTIFIER ::= { vmMIB 1 }
   vmConformance   OBJECT IDENTIFIER ::= { vmMIB 2 }


   -- Textual conversion definitions
   --
   VirtualMachineIndex ::= TEXTUAL-CONVENTION
       DISPLAY-HINT "d"
       STATUS       current
       DESCRIPTION
               "A unique value, greater than zero, identifying a
               virtual machine.  The value for each virtual machine
               must remain constant at least from one re-initialization
               of the hypervisor to the next re-initialization."
       SYNTAX       Integer32 (1..2147483647)

   VirtualMachineIndexOrZero ::= TEXTUAL-CONVENTION
       DISPLAY-HINT "d"
       STATUS       current
       DESCRIPTION
               "This textual convention is an extension of the
               VirtualMachineIndex convention.  This extension permits
               the additional value of zero.  The meaning of the value
               zero is object-specific and must therefore be defined as
               part of the description of any object which uses this
               syntax.  Examples of the usage of zero might include
               situations where a virtual machine is unknown, or when
               none or all virtual machines need to be referenced."
       SYNTAX       Integer32 (0..2147483647)

   VirtualMachineAdminState ::= TEXTUAL-CONVENTION
       STATUS      current
       DESCRIPTION
               "The administrative state of a virtual machine:

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

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

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

               destroy(5)    The administrative state of the virtual
                             machine indicating the virtual machine
                             should be forcibly shutdown.  After the
                             destroy operation, the administrative
                             state should be automatically changed to
                             shutdown(4)."
       SYNTAX       INTEGER {
                       running(1),
                       suspend(2),
                       pause(3),
                       shutdown(4),
                       destroy(5)
                    }

   VirtualMachineOperState ::= TEXTUAL-CONVENTION
       STATUS       current
       DESCRIPTION
               "The operational state of a virtual machine:

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

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

               preparing(3)   The operational state of the virtual
                              machine indicating the virtual machine is
                              currently in the process of preparation,
                              e.g., allocating and initializing virtual
                              storage after creating (defining) virtual
                              machine.

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

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

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

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

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

               paused(9)      The operational state of the virtual
                              machine indicating the virtual machine is
                              resident in memory but no longer
                              scheduled to execute by the hypervisor.
               migrating(10)  The operational state of the virtual
                              machine indicating the virtual machine is
                              currently in the process of migration
                              from/to another hypervisor.

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

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

               crashed(13)    The operational state of the virtual
                              machine indicating the virtual machine
                              has crashed."
       SYNTAX       INTEGER {
                       unknown(1),
                       other(2),
                       preparing(3),
                       running(4),
                       blocked(5),
                       suspending(6),
                       suspended(7),
                       resuming(8),
                       paused(9),
                       migrating(10),
                       shuttingdown(11),
                       shutdown(12),
                       crashed(13)
                    }

   VirtualMachineAutoStart ::= TEXTUAL-CONVENTION
       STATUS       current
       DESCRIPTION
               "The autostart configuration of a virtual machine:

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

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

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

               disable(3)     The autostart configuration of the
                              virtual machine is disabled.  The virtual
                              machine should not be automatically
                              brought online at the next
                              re-initialization of the hypervisor."
       SYNTAX      INTEGER {
                       unknown(1),
                       enable(2),
                       disable(3)
                   }

   VirtualMachinePersistent ::= TEXTUAL-CONVENTION
       STATUS       current
       DESCRIPTION
               "This value indicates whether a virtual machine has a
               persistent configuration which means the virtual machine
               will still exist after shutting down:

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

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

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

   VirtualMachineCpuIndex ::= TEXTUAL-CONVENTION
       DISPLAY-HINT "d"
       STATUS       current
       DESCRIPTION
               "A unique value for each virtual machine, greater than
               zero, identifying a virtual CPU assigned to a virtual
               machine.  The value for each virtual CPU must remain
               constant at least from one re-initialization of the
               hypervisor to the next re-initialization."
        SYNTAX      Integer32 (1..2147483647)

   VirtualMachineStorageIndex ::= TEXTUAL-CONVENTION
       DISPLAY-HINT "d"
       STATUS       current
       DESCRIPTION
               "A unique value for each virtual machine, greater than
               zero, identifying a virtual storage device allocated to
               a virtual machine.  The value for each virtual storage
               device must remain constant at least from one
               re-initialization of the hypervisor to the next
               re-initialization."
        SYNTAX      Integer32 (1..2147483647)

   VirtualMachineStorageSourceType ::= TEXTUAL-CONVENTION
       STATUS       current
       DESCRIPTION
               "The source type of a virtual storage device:

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

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

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

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

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

               network(6)     The source type is a network device."
       SYNTAX       INTEGER {
                       unknown(1),
                       other(2),
                       block(3),
                       raw(4),
                       sparse(5),
                       network(6)
                    }

   VirtualMachineStorageAccess ::= TEXTUAL-CONVENTION
       STATUS       current
       DESCRIPTION
               "The access permission of a virtual storage:
```

```
               readwrite(1)   The virtual storage is a read-write
                              device.

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

   VirtualMachineStorageMediaType ::= TEXTUAL-CONVENTION
       STATUS       current
       DESCRIPTION
               "The media type of a virtual storage device:

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

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

               hardDisk(3)    The media type is hard disk.

               opticalDisk(4) The media type is optical disk."
       SYNTAX       INTEGER {
                       other(1),
                       unknown(2),
                       hardDisk(3),
                       opticalDisk(4)
                    }

   VirtualMachineNetworkIndex ::= TEXTUAL-CONVENTION
       DISPLAY-HINT "d"
       STATUS       current
       DESCRIPTION
               "A unique value for each virtual machine, greater than
               zero, identifying a virtual network interface allocated
               to the virtual machine.  The value for each virtual
               network interface must remain constant at least from one
               re-initialization of the hypervisor to the next
               re-initialization."
        SYNTAX      Integer32 (1..2147483647)

   VirtualMachineList ::= TEXTUAL-CONVENTION
       DISPLAY-HINT "1x"
       STATUS       current
       DESCRIPTION
```

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

   -- The hypervisor group
   --
   -- A collection of objects common to all hypervisors.
   --
   vmHypervisor    OBJECT IDENTIFIER ::= { vmObjects 1 }

   vmHvSoftware OBJECT-TYPE
       SYNTAX       SnmpAdminString (SIZE (0..255))
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "A textual description of the hypervisor software.  This
               value should not include its version, and it should be
               included in ‘vmHvVersion’."
       ::= { vmHypervisor 1 }

   vmHvVersion OBJECT-TYPE
       SYNTAX       SnmpAdminString (SIZE (0..255))
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "A textual description of the version of the hypervisor
               software."
       ::= { vmHypervisor 2 }

   vmHvObjectID OBJECT-TYPE
       SYNTAX       OBJECT IDENTIFIER
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "The vendor’s authoritative identification of the
               hypervisor software contained in the entity.  This value
               is allocated within the SMI enterprises
               subtree (1.3.6.1.4.1).  Note that this is different from
```

```
                sysObjectID in the SNMPv2-MIB [RFC3418] because
                sysObjectID is not the identification of the hypervisor
                software but the device, firmware, or management
                operating system."
        ::= { vmHypervisor 3 }

    vmHvUpTime OBJECT-TYPE
        SYNTAX       TimeTicks
        MAX-ACCESS   read-only
        STATUS       current
        DESCRIPTION
                "The time (in centi-seconds) since the hypervisor was
                last re-initialized.  Note that this is different from
                sysUpTime in the SNMPv2-MIB [RFC3418] and hrSystemUptime
                in the HOST-RESOURCES-MIB [RFC2790] because sysUpTime is
                the uptime of the network management portion of the
                system, and hrSystemUptime is the uptime of the
                management operating system but not the hypervisor
                software."
        ::= { vmHypervisor 4 }


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

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

    vmTable OBJECT-TYPE
        SYNTAX       SEQUENCE OF VmEntry
        MAX-ACCESS   not-accessible
        STATUS       current
```

```
       DESCRIPTION
               "A list of virtual machine entries.  The number of
               entries is given by the value of vmNumber."
       ::= { vmObjects 4 }

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

   VmEntry ::=
       SEQUENCE {
           vmIndex                  VirtualMachineIndex,
           vmName                   SnmpAdminString,
           vmUUID                   UUIDorZero,
           vmOSType                 SnmpAdminString,
           vmAdminState             VirtualMachineAdminState,
           vmOperState              VirtualMachineOperState,
           vmAutoStart              VirtualMachineAutoStart,
           vmPersistent             VirtualMachinePersistent,
           vmCurCpuNumber           Integer32,
           vmMinCpuNumber           Integer32,
           vmMaxCpuNumber           Integer32,
           vmMemUnit                Integer32,
           vmCurMem                 Integer32,
           vmMinMem                 Integer32,
           vmMaxMem                 Integer32,
           vmUpTime                 TimeTicks,
           vmCpuTime                Counter64
       }

   vmIndex OBJECT-TYPE
       SYNTAX       VirtualMachineIndex
       MAX-ACCESS   not-accessible
       STATUS       current
       DESCRIPTION
               "A unique value, greater than zero, identifying the
               virtual machine. The value assigned to a given virtual
               machine may not persist across re-initialization of the
               hypervisor.  A command generator must use the vmUUID to
               identify a given virtual machine of interest."
       ::= { vmEntry 1 }
   vmName OBJECT-TYPE
       SYNTAX       SnmpAdminString (SIZE (0..255))
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "A textual name of the virtual machine."
       ::= { vmEntry 2 }

   vmUUID OBJECT-TYPE
       SYNTAX       UUIDorZero
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "The virtual machine’s 128-bit UUID or the zero-length
               string when a UUID is not available.  The UUID if set
               must uniquely identify a virtual machine from all other
               virtual machines in an administrative region.  A
               zero-length octet string is returned if no UUID
               information is known."
       ::= { vmEntry 3 }

   vmOSType OBJECT-TYPE
       SYNTAX       SnmpAdminString (SIZE (0..255))
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "A textual description containing operating system
               information installed on the virtual machine.  This
               value corresponds to the operating system the hypervisor
               assumes to be running when the virtual machine is
               started.  This may differ from the actual operating
               system in case the virtual machine boots into a
               different operating system."
       ::= { vmEntry 4 }

   vmAdminState OBJECT-TYPE
       SYNTAX       VirtualMachineAdminState
       MAX-ACCESS   read-write
       STATUS       current
       DESCRIPTION
               "The administrative power state of the virtual machine.
               Note that a virtual machine is supposed to be resumed
               when vmAdminState of the virtual machine is changed from
               suspended(2) or paused(3) to running(1)."
       ::= { vmEntry 5 }

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

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

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

   vmCurCpuNumber OBJECT-TYPE
       SYNTAX       Integer32 (0..2147483647)
       MAX-ACCESS   read-write
       STATUS       current
       DESCRIPTION
               "The number of virtual CPUs currently assigned to the
               virtual machine.  Changes to this object MUST NOT
               persist across re-initialization of the hypervisor."
       ::= { vmEntry 9 }

   vmMinCpuNumber OBJECT-TYPE
       SYNTAX       Integer32 (-1|0..2147483647)
       MAX-ACCESS   read-write
       STATUS       current
       DESCRIPTION
               "The minimum number of virtual CPUs that are assigned to
               the virtual machine when it is in a power-on state.  The
               value -1 indicates that there is no hard boundary for
               the minimum number of virtual CPUs.  Changes to this
               object MUST NOT persist across re-initialization of the
               hypervisor."
       ::= { vmEntry 10 }

   vmMaxCpuNumber OBJECT-TYPE
       SYNTAX       Integer32 (-1|0..2147483647)
       MAX-ACCESS   read-write
       STATUS       current
       DESCRIPTION
               "The maximum number of virtual CPUs that are assigned to
               the virtual machine when it is in a power-on state.  The
               value -1 indicates that there is no limit.  Changes to
               this object MUST NOT persist across re-initialization of
               the hypervisor."
       ::= { vmEntry 11 }

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

   vmCurMem OBJECT-TYPE
       SYNTAX       Integer32 (0..2147483647)
       MAX-ACCESS   read-write
       STATUS       current
       DESCRIPTION
               "The current memory size currently allocated to the
               virtual memory module in the unit designated by
               vmMemUnit.  Changes to this object MUST NOT persist
               across re-initialization of the hypervisor."
       ::= { vmEntry 13 }

   vmMinMem OBJECT-TYPE
       SYNTAX       Integer32 (-1|0..2147483647)
       MAX-ACCESS   read-write
       STATUS       current
       DESCRIPTION
               "The minimum memory size defined to the virtual machine
               in the unit designated by vmMemUnit.  The value -1
               indicates that there is no hard boundary for the minimum
               memory size.  Changes to this object MUST NOT persist
               across re-initialization of the hypervisor."
       ::= { vmEntry 14 }
   vmMaxMem OBJECT-TYPE
       SYNTAX       Integer32 (-1|0..2147483647)
       MAX-ACCESS   read-write
       STATUS       current
       DESCRIPTION
               "The maximum memory size defined to the virtual machine
               in the unit designated by vmMemUnit.  The value -1
               indicates that there is no limit.  Changes to this
               object MUST NOT persist across re-initialization of the
               hypervisor."
       ::= { vmEntry 15 }


   vmUpTime OBJECT-TYPE
       SYNTAX       TimeTicks
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "The time (in centi-seconds) since the administrative
               state of the virtual machine was last changed from
               shutdown(4) to running(1)."
       ::= { vmEntry 16 }

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

               Discontinuities in the value of this counter can occur
               at re-initialization of the hypervisor, and
               administrative state (vmAdminState) changes of the
               virtual machine."
       ::= { vmEntry 17 }

   -- The virtual CPU on each virtual machines
   vmCpuTable OBJECT-TYPE
       SYNTAX       SEQUENCE OF VmCpuEntry
       MAX-ACCESS   not-accessible
       STATUS       current
       DESCRIPTION
               "The table of virtual CPUs provided by the hypervisor."
       ::= { vmObjects 5 }
   vmCpuEntry OBJECT-TYPE
       SYNTAX       VmCpuEntry
       MAX-ACCESS   not-accessible
       STATUS       current
       DESCRIPTION
               "An entry for one virtual processor assigned to a
               virtual machine."
       INDEX { vmIndex, vmCpuIndex }
       ::= { vmCpuTable 1 }

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

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

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

               Discontinuities in the value of this counter can occur
               at re-initialization of the hypervisor, and
               administrative state (vmAdminState) changes of the
               virtual machine."
       ::= { vmCpuEntry 2 }

   -- The virtual CPU affinity on each virtual machines
   vmCpuAffinityTable OBJECT-TYPE
       SYNTAX       SEQUENCE OF VmCpuAffinityEntry
       MAX-ACCESS   not-accessible
       STATUS       current
       DESCRIPTION
               "A list of CPU affinity entries of a virtual CPU."
       ::= { vmObjects 6 }
   vmCpuAffinityEntry OBJECT-TYPE
       SYNTAX       VmCpuAffinityEntry
       MAX-ACCESS   not-accessible
       STATUS       current
       DESCRIPTION
               "An entry containing CPU affinity associated with a
               particular virtual machine."
       INDEX   { vmIndex, vmCpuIndex, vmCpuPhysIndex }
       ::= { vmCpuAffinityTable 1 }

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

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

   vmCpuAffinity OBJECT-TYPE
       SYNTAX       INTEGER {
                       unknown(0),   -- unknown
                       enable(1),    -- enabled
                       disable(2)    -- disabled
                    }
       MAX-ACCESS   read-write
       STATUS       current
       DESCRIPTION
               "The CPU affinity of this virtual CPU to the physical
               CPU represented by ‘vmCpuPhysIndex’."
       ::= { vmCpuAffinityEntry 3 }


   -- The virtual storage devices on each virtual machine.  This
   -- document defines some overlapped objects with hrStorage in
   -- HOST-RESOURCES-MIB [RFC2790], because virtual resources shall be
   -- allocated from the hypervisor’s resources, which is the ‘host
   -- resources’
   vmStorageTable OBJECT-TYPE
       SYNTAX       SEQUENCE OF VmStorageEntry
       MAX-ACCESS   not-accessible
       STATUS       current
       DESCRIPTION
               "The conceptual table of virtual storage devices
               attached to the virtual machine."
       ::= { vmObjects 7 }

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

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

   vmStorageVmIndex OBJECT-TYPE
       SYNTAX       VirtualMachineIndexOrZero
       MAX-ACCESS   not-accessible
       STATUS       current
       DESCRIPTION
               "This value identifies the virtual machine (guest) this
               storage device has been allocated to.  The value zero
               indicates that the storage device is currently not
               allocated to any virtual machines."
       ::= { vmStorageEntry 1 }
   vmStorageIndex OBJECT-TYPE
       SYNTAX       VirtualMachineStorageIndex
       MAX-ACCESS   not-accessible
       STATUS       current
       DESCRIPTION
               "A unique value identifying a virtual storage device
               allocated to the virtual machine."
       ::= { vmStorageEntry 2 }

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

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

   vmStorageSourceTypeString OBJECT-TYPE
       SYNTAX       SnmpAdminString (SIZE (0..255))
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "A (detailed) textual string of the source type of the
               virtual storage device.  For example, this represents
               the specific format name of the sparse file."
       ::= { vmStorageEntry 5 }

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

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

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

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

   vmStorageSizeUnit OBJECT-TYPE
       SYNTAX       Integer32 (1..2147483647)
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "The multiplication unit for vmStorageDefinedSize and
               vmStorageAllocatedSize.  For example, when this value is
               1048576, the storage size unit for vmStorageDefinedSize
               and vmStorageAllocatedSize is MiB."
       ::= { vmStorageEntry 10 }

   vmStorageDefinedSize OBJECT-TYPE
       SYNTAX       Integer32 (-1|0..2147483647)
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "The defined virtual storage size defined in the unit
               designated by vmStorageSizeUnit.  If this information is
               not available, this value shall be -1."
       ::= { vmStorageEntry 11 }
   vmStorageAllocatedSize OBJECT-TYPE
       SYNTAX       Integer32 (-1|0..2147483647)
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "The storage size allocated to the virtual storage from
               a physical storage in the unit designated by
               vmStorageSizeUnit.  When the virtual storage is block
               device or raw file, this value and vmStorageDefinedSize
               are supposed to equal.  This value MUST NOT be different
               from vmStorageDefinedSize when vmStorageSourceType is
               ‘block’ or ‘raw’.  If this information is not available,
               this value shall be -1."
       ::= { vmStorageEntry 12 }

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

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

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

               Discontinuities in the value of this counter can occur
               at re-initialization of the hypervisor, and
               administrative state (vmAdminState) changes of the
               virtual machine."
       ::= { vmStorageEntry 14 }

   -- The virtual network interfaces on each virtual machine.
   vmNetworkTable OBJECT-TYPE
       SYNTAX       SEQUENCE OF VmNetworkEntry
       MAX-ACCESS   not-accessible
       STATUS       current
       DESCRIPTION
               "The conceptual table of virtual network interfaces
```

```
                attached to the virtual machine."
        ::= { vmObjects 8 }

    vmNetworkEntry OBJECT-TYPE
        SYNTAX       VmNetworkEntry
        MAX-ACCESS   not-accessible
        STATUS       current
        DESCRIPTION
                "An entry for one virtual network interfaces attached to
                the virtual machine."
        INDEX { vmIndex, vmNetworkIndex }
        ::= { vmNetworkTable 1 }

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

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

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

    vmNetworkParent OBJECT-TYPE
        SYNTAX       InterfaceIndexOrZero
        MAX-ACCESS   read-only
        STATUS       current
        DESCRIPTION
                "The value of ifIndex which corresponds to the parent
                (i.e., physical) device of this virtual device on.  The
```

```
               value zero denotes this virtual device is not any child
               represented in the ifTable."
       ::= { vmNetworkEntry 3 }

   vmNetworkModel OBJECT-TYPE
       SYNTAX       SnmpAdminString (SIZE (0..255))
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "A textual string containing the (emulated) model of
               virtual network interface.  For example, this value is
               ‘virtio’ when the emulation driver model is virtio."
       ::= { vmNetworkEntry 4 }

   vmNetworkPhysAddress OBJECT-TYPE
       SYNTAX       PhysAddress
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "The MAC address of the virtual network interface."
       ::= { vmNetworkEntry 5 }


   -- Notification definitions:

   vmPerVMNotificationsEnabled OBJECT-TYPE
       SYNTAX       TruthValue
       MAX-ACCESS   read-write
       STATUS       current
       DESCRIPTION
               "Indicates if notification generator will send
               notifications per virtual machine."
       ::= { vmObjects 9 }

   vmBulkNotificationsEnabled OBJECT-TYPE
       SYNTAX       TruthValue
       MAX-ACCESS   read-write
       STATUS       current
       DESCRIPTION
               "Indicates if notification generator will send
               notifications per set of virtual machines."
       ::= { vmObjects 10 }

   vmAffectedVMs OBJECT-TYPE
       SYNTAX       VirtualMachineList
       MAX-ACCESS   accessible-for-notify
       STATUS       current
       DESCRIPTION
```

```
               "A complete list of virtual machines whose state has
               changed.  This object is the only object sent with bulk
               notifications."
       ::= { vmObjects 11 }

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

   vmShutdown NOTIFICATION-TYPE
       OBJECTS      {
                       vmName,
                       vmUUID,
                       vmOperState
                    }
       STATUS       current
       DESCRIPTION
               "This notification is generated when the operational
               state of a virtual machine has been changed to
               shutdown(12) from some other state.  The other state is
               indicated by the included value of vmOperState."
       ::= { vmNotifications 2 }

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

   vmPaused NOTIFICATION-TYPE
```

```
       OBJECTS      {
                       vmName,
                       vmUUID,
                       vmOperState
                    }
       STATUS       current
       DESCRIPTION
               "This notification is generated when the operational
               state of a virtual machine has been changed to
               paused(9) from some other state.  The other state is
               indicated by the included value of vmOperState."
       ::= { vmNotifications 4 }

   vmSuspending NOTIFICATION-TYPE
       OBJECTS      {
                       vmName,
                       vmUUID,
                       vmOperState
                    }
       STATUS       current
       DESCRIPTION
               "This notification is generated when the operational
               state of a virtual machine has been changed to
               suspending(6) from some other state.  The other state is
               indicated by the included value of vmOperState."
       ::= { vmNotifications 5 }

   vmSuspended NOTIFICATION-TYPE
       OBJECTS      {
                       vmName,
                       vmUUID,
                       vmOperState
                    }
       STATUS       current
       DESCRIPTION
               "This notification is generated when the operational
               state of a virtual machine has been changed to
               suspended(7) from some other state.  The other state is
               indicated by the included value of vmOperState."
       ::= { vmNotifications 6 }

   vmResuming NOTIFICATION-TYPE
       OBJECTS      {
                       vmName,
                       vmUUID,
                       vmOperState
                    }
       STATUS       current
       DESCRIPTION
               "This notification is generated when the operational
               state of a virtual machine has been changed to
               resuming(8) from some other state.  The other state is
               indicated by the included value of vmOperState."
       ::= { vmNotifications 7 }

   vmMigrating NOTIFICATION-TYPE
       OBJECTS      {
                       vmName,
                       vmUUID,
                       vmOperState
                    }
       STATUS       current
       DESCRIPTION
               "This notification is generated when the operational
               state of a virtual machine has been changed to
               migrating(10) from some other state.  The other state is
               indicated by the included value of vmOperState."
       ::= { vmNotifications 8 }

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

   vmBlocked NOTIFICATION-TYPE
       OBJECTS      {
                       vmName,
                       vmUUID,
                       vmOperState
                    }
       STATUS       current
       DESCRIPTION
               "This notification is generated when the operational
               state of a virtual machine has been changed to
               blocked(5).  The previos state of the virtual machine is
               indicated by the included value of vmOperState."
       ::= { vmNotifications 10 }
   vmDeleted NOTIFICATION-TYPE
       OBJECTS      {
                       vmName,
                       vmUUID,
                       vmOperState,
                       vmPersistent
                    }
       STATUS       current
       DESCRIPTION
               "This notification is generated when a virtual machine
               has been deleted. The prior state of the virtual
               machine is indicated by the included value of
               vmOperState."
       ::= { vmNotifications 11 }

   vmBulkRunning NOTIFICATION-TYPE
       OBJECTS      {
                       vmAffectedVMs
                    }
       STATUS       current
       DESCRIPTION
               "This notification is generated when the operational
               state of one or more virtual machine has been changed to
               running(4) from a all prior states except for
               running(4).  Management stations are encouraged to
               subsequently poll the subset of virtual machines of
               interest for vmOperState."
       ::= { vmNotifications 12 }

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

   vmBulkShutdown NOTIFICATION-TYPE
       OBJECTS      {
                      vmAffectedVMs
                    }
       STATUS       current
       DESCRIPTION
               "This notification is generated when the operational
               state of one or more virtual machine has been changed to
               shutdown(12) from a state other than shutdown(12).
               Management stations are encouraged to subsequently poll
               the subset of virtual machines of interest for
               vmOperState."
       ::= { vmNotifications 14 }

   vmBulkPaused NOTIFICATION-TYPE
       OBJECTS      {
                       vmAffectedVMs
                    }
       STATUS       current
       DESCRIPTION
               "This notification is generated when the operational
               state of one or more virtual machines have been changed
               to paused(9) from a state other than paused(9).
               Management stations are encouraged to subsequently poll
               the subset of virtual machines of interest for
               vmOperState."
       ::= { vmNotifications 15 }


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

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

   vmBulkResuming NOTIFICATION-TYPE
       OBJECTS      {
                       vmAffectedVMs
                    }
       STATUS       current
       DESCRIPTION
               "This notification is generated when the operational
               state of one or more virtual machines have been changed
               to resuming(8) from a state other than resuming(8).
               Management stations are encouraged to subsequently poll
               the subset of virtual machines of interest for
               vmOperState."
       ::= { vmNotifications 18 }

   vmBulkMigrating NOTIFICATION-TYPE
       OBJECTS      {
                       vmAffectedVMs
                    }
       STATUS       current
       DESCRIPTION
               "This notification is generated when the operational
               state of one or more virtual machines have been changed
               to migrating(10) from a state other than migrating(10).
               Management stations are encouraged to subsequently poll
               the subset of virtual machines of interest for
               vmOperState."
       ::= { vmNotifications 19 }

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

   vmBulkBlocked NOTIFICATION-TYPE
       OBJECTS      {
                       vmAffectedVMs
                    }
       STATUS       current
       DESCRIPTION
               "This notification is generated when the operational
               state of one or more virtual machines have been changed
               to blocked(5) from a state other than blocked(5).
               Management stations are encouraged to subsequently poll
               the subset of virtual machines of interest for
               vmOperState."
       ::= { vmNotifications 21 }

   vmBulkDeleted NOTIFICATION-TYPE
       OBJECTS      {
                       vmAffectedVMs
                    }
       STATUS       current
       DESCRIPTION
               "This notification is generated when one or more virtual
               machines have been deleted.  Management stations are
               encouraged to subsequently poll the subset of virtual
               machines of interest for vmOperState."
       ::= { vmNotifications 22 }

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

   vmFullCompliances MODULE-COMPLIANCE
       STATUS       current
       DESCRIPTION
               "Compliance statement for implementations supporting
               read/write access, according to the object definitions."
       MODULE     -- this module
       MANDATORY-GROUPS {
           vmHypervisorGroup,
           vmVirtualMachineGroup,
           vmCpuGroup,
           vmCpuAffinityGroup,
           vmStorageGroup,
           vmNetworkGroup
       }
       GROUP  vmPerVMNotificationOptionalGroup
       DESCRIPTION
               "Support for per-VM notifications is optional.  If not
               implemented then vmPerVMNotificationsEnabled must report
               false(2)."
       GROUP  vmBulkNotificationsVariablesGroup
       DESCRIPTION
               "Necessary only if vmPerVMNotificationOptionalGroup is
```

```
                implemented."
        GROUP  vmBulkNotificationOptionalGroup
        DESCRIPTION
                "Support for bulk notifications is optional.  If not
                implemented then vmBulkNotificationsEnabled must report
                false(2)."

        ::= { vmCompliances 1 }

    vmReadOnlyCompliances MODULE-COMPLIANCE
        STATUS       current
        DESCRIPTION
                "Compliance statement for implementations supporting
                only readonly access."
        MODULE     -- this module
        MANDATORY-GROUPS {
            vmHypervisorGroup,
            vmVirtualMachineGroup,
            vmCpuGroup,
            vmCpuAffinityGroup,
            vmStorageGroup,
            vmNetworkGroup
        }

        OBJECT vmAdminState
        MIN-ACCESS   read-only
        DESCRIPTION
                "Write access is not required."

        OBJECT vmCurCpuNumber
        MIN-ACCESS   read-only
        DESCRIPTION
                "Write access is not required."

        OBJECT vmMinCpuNumber
        MIN-ACCESS   read-only
        DESCRIPTION
                "Write access is not required."

        OBJECT vmMaxCpuNumber
        MIN-ACCESS   read-only
        DESCRIPTION
                "Write access is not required."

        OBJECT vmCurMem
        MIN-ACCESS   read-only
        DESCRIPTION
                "Write access is not required."
```

```
       OBJECT vmMinMem
       MIN-ACCESS   read-only
       DESCRIPTION
               "Write access is not required."

       OBJECT vmMaxMem
       MIN-ACCESS   read-only
       DESCRIPTION
               "Write access is not required."

       OBJECT vmCpuAffinity
       MIN-ACCESS   read-only
       DESCRIPTION
               "Write access is not required."

       OBJECT vmPerVMNotificationsEnabled
       MIN-ACCESS   read-only
       DESCRIPTION
               "Write access is not required."

       OBJECT vmBulkNotificationsEnabled
       MIN-ACCESS   read-only
       DESCRIPTION
               "Write access is not required."
       ::= { vmCompliances 2 }

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

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

   vmCpuGroup OBJECT-GROUP
       OBJECTS {
           -- vmCpuIndex,
           vmCpuCoreTime
       }
       STATUS       current
       DESCRIPTION
               "A collection of objects providing insight into the
               virtual machines) controlled by a hypervisor."
       ::= { vmGroups 3 }

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

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

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

   vmPerVMNotificationOptionalGroup NOTIFICATION-GROUP
       NOTIFICATIONS {
           vmRunning,
           vmShuttingdown,
           vmShutdown,
           vmPaused,
           vmSuspending,
           vmSuspended,
           vmResuming,
           vmMigrating,
           vmCrashed,
           vmBlocked,
           vmDeleted
       }
       STATUS       current
       DESCRIPTION
```

```
               "A collection of notifications for per-VM notification
               of changes to virtual machine state (vmOperState) as
               reported by a hypervisor."
       ::= { vmGroups 7 }

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

   vmBulkNotificationOptionalGroup NOTIFICATION-GROUP
       NOTIFICATIONS {
           vmBulkRunning,
           vmBulkShuttingdown,
           vmBulkShutdown,
           vmBulkPaused,
           vmBulkSuspending,
           vmBulkSuspended,
           vmBulkResuming,
           vmBulkMigrating,
           vmBulkCrashed,
           vmBulkBlocked,
           vmBulkDeleted
       }
       STATUS       current
       DESCRIPTION
               "A collection of notifications for bulk notification of
               changes to virtual machine state (vmOperState) as
               reported by a given hypervisor."
       ::= { vmGroups 9 }

   END
```

4. IANA Considerations

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

Descriptor	OBJECT IDENTIFIER value
vmMIB	{ mib-2 TBD }

5. Security Considerations

There are a number of management objects defined in this MIB that have a MAX-ACCESS clause of read-write and/or read-create. Such objects may be considered sensitive or vulnerable in some network environments. The support for SET operations in a non-secure environment without proper protection can have a negative effect on hypervisor and virtual machine operations.

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

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

It is recommended that attention be specifically given to implementing the MAX-ACCESS clause in a number of objects, including vmAdminState, vmMinCpuNumber, vmMaxCpuNumber, vmMinMem, vmMaxMem, and vmCpuAffinity in scenarios that DO NOT use SNMPv3 strong security (i.e. authentication and encryption). Extreme caution must be used to minimize the risk of cascading security vulnerabilities when SNMPv3 strong security is not used. When SNMPv3 strong security is not used, these objects should have access of read-only, not read-create.

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

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

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

6. Acknowledgements

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

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

7. References

7.1. Normative References

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.

[RFC2578] McCloghrie, K., Ed., Perkins, D., Ed., and J. Schoenwaelder, Ed., "Structure of Management Information Version 2 (SMIv2)", STD 58, RFC 2578, April 1999.

[RFC2579] McCloghrie, K., Ed., Perkins, D., Ed., and J. Schoenwaelder, Ed., "Textual Conventions for SMIv2", STD 58, RFC 2579, April 1999.

[RFC2580] McCloghrie, K., Perkins, D., and J. Schoenwaelder, "Conformance Statements for SMIv2", STD 58, RFC 2580, April 1999.

[RFC2790] Waldbusser, S. and P. Grillo, "Host Resources MIB", RFC 2790, March 2000.

[RFC2863] McCloghrie, K. and F. Kastenholz, "The Interfaces Group MIB", RFC 2863, June 2000.

[RFC3413] Levi, D., Meyer, P., and B. Stewart, "Simple Network Management Protocol (SNMP) Applications", STD 62, RFC 3413, December 2002.

[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, December 2002.

[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, December 2002.

[RFC3418] Presuhn, R., "Management Information Base (MIB) for the Simple Network Management Protocol (SNMP)", STD 62, RFC 3418, December 2002.

[RFC4122] Leach, P., Mealling, M., and R. Salz, "A Universally Unique IDentifier (UUID) URN Namespace", RFC 4122, July 2005.

[RFC4133] Bierman, A. and K. McCloghrie, "Entity MIB (Version 3)", RFC 4133, August 2005.

[RFC4188] Norseth, K. and E. Bell, "Definitions of Managed Objects for Bridges", RFC 4188, September 2005.

[RFC4363] Levi, D. and D. Harrington, "Definitions of Managed Objects for Bridges with Traffic Classes, Multicast Filtering, and Virtual LAN Extensions", RFC 4363, January 2006.

7.2. Informative References

[RFC3410] Case, J., Mundy, R., Partain, D., and B. Stewart, "Introduction and Applicability Statements for Internet-Standard Management Framework", RFC 3410, December 2002.

Appendix A. State Transition Table

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

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

State transition table

Authors' Addresses

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

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

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

Email: sekiya@wide.ad.jp

Keiichi Shima
IIJ Innovation Institute Inc.
3-13 Kanda-Nishikicho
Chiyoda-ku, Tokyo 101-0054
JP

Email: keiichi@iijlab.net

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

Email: tina.tsou.zouting@huawei.com

Cathy Zhou
Huawei Technologies
Bantian, Longgang District
Shenzhen 518129
P.R. China

Email: cathyzhou@huawei.com

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

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