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Definition of Managed Objects for Battery Monitoring

Abstract

This memo defines a portion of the Management Information Base (MIB) for use with network management protocols in the Internet community. In particular, it defines managed objects that provide information on the status of batteries in managed devices.

Status of This Memo

This is an Internet Standards Track document.

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1. Introduction

Today, more and more managed devices contain batteries that supply them with power when disconnected from electrical power distribution grids. Common examples are nomadic and mobile devices, such as notebook computers, netbooks, and smartphones. The status of batteries in such a device, particularly the charging status, is typically controlled by automatic functions that act locally on the device and manually by users of the device.

In addition to this, there is a need to monitor battery status of these devices by network management systems. This document defines a portion of the Management Information Base (MIB) that provides a means for monitoring batteries in or attached to managed devices. The Battery MIB module defined in Section 4 meets the requirements for monitoring the status of batteries specified in RFC 6988 [RFC6988].

The Battery MIB module provides for monitoring the battery status. According to the framework for energy management [RFC7326], it is an Energy Managed Object; thus, MIB modules such as the Power and Energy Monitoring MIB [RFC7460] could, in principle, be implemented for batteries. The Battery MIB extends the more generic aspects of energy management by adding battery-specific information. Amongst other things, the Battery MIB enables the monitoring of:

- o the current charge of a battery,
- o the age of a battery (charging cycles),
- o the state of a battery (e.g., being recharged),
- o last usage of a battery, and
- o maximum energy provided by a battery (remaining and total capacity).

Further, means are provided for battery-powered devices to send notifications to inform the management system of needed replacement when the current battery charge has dropped below a certain threshold. The same applies to the age of a battery.

Many battery-driven devices have existing instrumentation for monitoring the battery status because this is already needed for local control of the battery by the device. This reduces the effort for implementing the managed objects defined in this document. For many devices, only additional software will be needed; no additional hardware instrumentation for battery monitoring is necessary.

Since there are a lot of devices in use that contain more than one battery, means for battery monitoring defined in this document support addressing multiple batteries within a single device. Also, batteries today often come in packages that can include identification and might contain additional hardware and firmware. The former allows tracing a battery and allows continuous monitoring even if the battery is installed in another device. The firmware version is useful information as the battery behavior might be different for different firmware versions.

Not explicitly in the scope of definitions in this document are very small backup batteries, for example, batteries used on a PC motherboard to run the clock circuit and retain configuration memory while the system is turned off. Other means may be required for reporting on these batteries. However, the MIB module defined in Section 3.1 can be used for this purpose.

A traditional type of managed device containing batteries is an Uninterruptible Power Supply (UPS) system; these supply other devices with electrical energy when the main power supply fails. There is already a MIB module for managing UPS systems defined in RFC 1628 [RFC1628]. The UPS MIB module includes managed objects for monitoring the batteries contained in a UPS system. However, the information provided by the UPS MIB objects is limited and tailored to the particular needs of UPS systems.

A huge variety of battery technologies are available, and they are evolving over time. For different applications, different battery technologies are preferable, for example, because of different weight, cost, robustness, charging time, etc. Some technologies, such as lead-acid batteries, are continuously in use for decades, while others, such as nickel-based battery technologies (nickel-cadmium and nickel-metal hydride), have, to a wide extent, been replaced by lithium-based battery technologies (lithium-ion and lithium polymer).

The Battery MIB module uses a generic abstraction of batteries that is independent of particular battery technologies and expected to be applicable to future technologies as well. While identification of a particular battery technology is supported by an extensible list of battery technology identifiers (see Section 3.2), individual properties of the technologies are not modeled by the abstraction. In particular, methods for charging a battery, and the parameters of those methods, which vary greatly between different technologies are not individually modeled.

Instead, the Battery MIB module uses a simple common charging model with batteries being in one of the following states: 'charging', 'maintaining charge', 'not charging', and 'discharging'. Control of the charging process is limited to requests for transitions between these states. For charging controllers that use charging state engines with more states, implementations of the Battery MIB module need to map those states to the four listed above.

For energy management systems that require finer-grained control of the battery charging process, additional means need to be developed; for example, MIB modules that model richer sets of charging states and parameters for charging states.

All use cases sketched above assume that the batteries are contained in a managed entity. In a typical case, this entity also hosts the SNMP applications (command responder and notification generator) and the charging controller for contained batteries. For definitions in this document, it is not strictly required that batteries be contained in the same managed entity, even though the Battery MIB module (defined further below) uses the containment tree of the Entity MIB module [RFC6933] for battery indexing.

External batteries can be supported as long as the charging controller for these batteries is connected to the SNMP applications that implement the Battery MIB module. An example with an external battery is shown in the figure below. It illustrates that the Battery MIB module is designed as an interface between the management system and battery charging controller. Out of scope of this

document is the interface between the battery charging controller and controlled batteries.

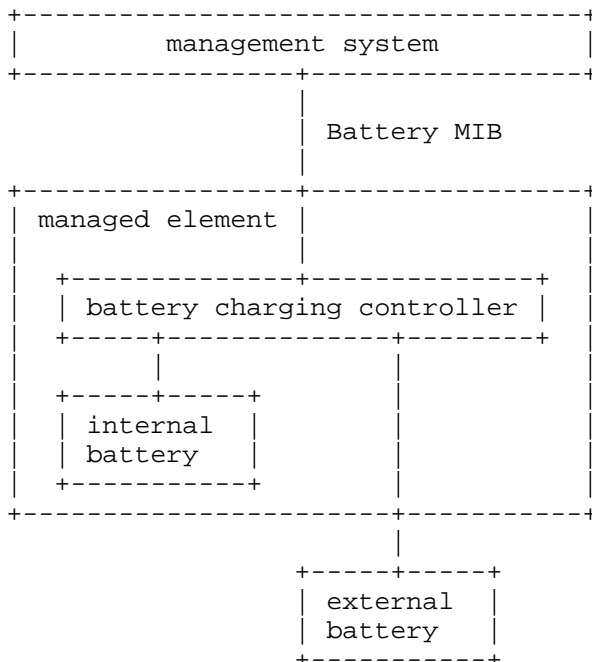


Figure 1: Battery MIB as Interface between Management System and Battery-Charging Controller Supporting External Batteries

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "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 MIB modules that are 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. Design of the Battery MIB Module

3.1. MIB Module Structure

The Battery MIB module defined in this document defines objects for reporting information about batteries. All managed objects providing information on the status of a battery are contained in a single table called "batteryTable". The batteryTable contains one conceptual row per battery.

Batteries are indexed by the entPhysicalIndex of the entPhysicalTable defined in the Entity MIB module [RFC6933]. An implementation of the Entity MIB module complying with the entity4CRCompliance MODULE-COMPLIANCE statement is required for compliant implementations of the Battery MIB module.

If a battery is replaced, and the replacing battery uses the same physical connector as the replaced battery, then the replacing battery MUST be indexed with the same value of object entPhysicalIndex as the replaced battery.

The kind of entity in the entPhysicalTable of the Entity MIB module is indicated by the value of enumeration object entPhysicalClass. All batteries SHOULD have the value of object entPhysicalClass set to battery(14) in their row of the entPhysicalTable.

The batteryTable contains three groups of objects. The first group (OIDs ending with 1-9) provides information on static properties of the battery. The second group of objects (OIDs ending with 10-18) provides information on the current battery state, if it is charging or discharging, how much it is charged, its remaining capacity, the number of experienced charging cycles, etc.

```

batteryTable(1)
+--batteryEntry(1) [entPhysicalIndex]
  +-- r-n SnmpAdminString batteryIdentifier(1)
  +-- r-n SnmpAdminString batteryFirmwareVersion(2)
  +-- r-n Enumeration batteryType(3)
  +-- r-n Unsigned32 batteryTechnology(4)
  +-- r-n Unsigned32 batteryDesignVoltage(5)
  +-- r-n Unsigned32 batteryNumberOfCells(6)
  +-- r-n Unsigned32 batteryDesignCapacity(7)
  +-- r-n Unsigned32 batteryMaxChargingCurrent(8)
  +-- r-n Unsigned32 batteryTrickleChargingCurrent(9)
  +-- r-n Unsigned32 batteryActualCapacity(10)
  +-- r-n Unsigned32 batteryChargingCycleCount(11)
  +-- r-n DateAndTime batteryLastChargingCycleTime(12)
  +-- r-n Enumeration batteryChargingOperState(13)
  +-- rwn Enumeration batteryChargingAdminState(14)
  +-- r-n Unsigned32 batteryActualCharge(15)
  +-- r-n Unsigned32 batteryActualVoltage(16)
  +-- r-n Integer32 batteryActualCurrent(17)
  +-- r-n Integer32 batteryTemperature(18)
  +-- rwn Unsigned32 batteryAlarmLowCharge(19)
  +-- rwn Unsigned32 batteryAlarmLowVoltage(20)
  +-- rwn Unsigned32 batteryAlarmLowCapacity(21)
  +-- rwn Unsigned32 batteryAlarmHighCycleCount(22)
  +-- rwn Integer32 batteryAlarmHighTemperature(23)
  +-- rwn Integer32 batteryAlarmLowTemperature(24)
  +-- r-n SnmpAdminString batteryCellIdentifier(25)

```

The third group of objects in this table (OIDs ending with 19-25) is used for notifications. Threshold objects (OIDs ending with 19-24) indicate thresholds that can be used to raise an alarm if a property of the battery exceeds one of them. Raising an alarm may include sending a notification.

The Battery MIB defines seven notifications for indicating:

1. a battery-charging state change that was not triggered by writing to object batteryChargingAdminState,
2. a low-battery charging state,
3. a critical-battery state in which it cannot be used for power supply,
4. an aged battery that may need to be replaced,
5. a battery that has exceeded a temperature threshold,

6. a battery that has been connected, and
7. disconnection of one or more batteries.

Notifications 2-5 can use object `batteryCellIdentifier` to indicate a specific cell or a set of cells within the battery that have triggered the notification.

3.2. Battery Technologies

Static information in the `batteryTable` includes battery type and technology. The battery type distinguishes primary (not rechargeable) batteries from rechargeable (secondary) batteries and capacitors. The battery technology describes the actual technology of a battery, which typically is a chemical technology.

Since battery technologies are the subject of intensive research and widely used technologies are often replaced by successor technologies within a few years, the list of battery technologies was not chosen as a fixed list. Instead, IANA has created a registry for battery technologies at <http://www.iana.org/assignments/battery-technologies> where numbers are assigned to battery technologies.

The table below shows battery technologies known today that are in commercial use with the numbers assigned to them by IANA. New entries can be added to the IANA registry if new technologies are developed or if missing technologies are identified. Note that there exists a huge number of battery types that are not listed in the IANA registry. Many of them are experimental or cannot be used in an economically useful way. New entries should be added to the IANA registry only if the respective technologies are in commercial use and relevant to standardized battery monitoring over the Internet.

Battery Technology	Value
Reserved	0
Unknown	1
Other	2
Zinc-carbon	3
Zinc chloride	4
Nickel oxyhydroxide	5
Lithium-copper oxide	6
Lithium-iron disulfide	7
Lithium-manganese dioxide	8
Zinc-air	9
Silver oxide	10
Alkaline	11
Lead-acid	12
Valve-Regulated Lead-Acid, Gel	13
Valve-Regulated Lead-Acid, AGM	14
Nickel-cadmium	15
Nickel-metal hydride	16
Nickel-zinc	17
Lithium-ion	18
Lithium polymer	19
Double layer capacitor	20
Unassigned	21-4294967295

3.2.1. Guidelines for Adding Battery Technologies

New entries can be added to the IANA registry if new technologies are developed or if missing technologies are identified. Note that there exists a huge number of battery types that are not listed in the IANA registry. Many of them are experimental or cannot be used in an economically useful way. New entries should be added to the IANA registry only if the respective technologies are in commercial use and relevant to standardized battery monitoring over the Internet.

3.3. Battery Identification

There are two identifiers to be used: the `entPhysicalUUID` defined in the Entity MIB [RFC6933] module and the `batteryIdentifier` defined in this module. A battery is linked to an `entPhysicalUUID` through the shared `entPhysicalIndex`.

The `batteryIdentifier` uniquely identifies the battery itself while the `entPhysicalUUID` identifies the slot of the device in which the battery is (currently) contained. For a non-replaceable battery, both identifiers are always linked to the same physical battery. But

for batteries that can be replaced, the identifiers have different functions.

The `entPhysicalUUID` is always the same for a certain battery slot of a containing device even if the contained battery is replaced by another. The `batteryIdentifier` is a representation of the battery identifier set by the battery manufacturer. It is tied to the battery and usually cannot be changed.

Many manufacturers deliver not just plain batteries but battery packages including additional hardware and firmware. Typically, these modules include a battery identifier that can be retrieved by a device in which a battery has been installed. The value of the object `batteryIdentifier` is an exact representation of this identifier. The `batteryIdentifier` is useful when batteries are removed and reinstalled in the same device or in other devices. Then, the device or the network management system can trace batteries and achieve continuity of battery monitoring.

3.4. Charging Cycles

The lifetime of a battery can be approximated using the measure of charging cycles. A commonly used definition of a charging cycle is the amount of discharge equal to the design (or nominal) capacity of the battery [SBS]. This means that a single charging cycle may include several steps of partial charging and discharging until the amount of discharging has reached the design capacity of the battery. After that, the next charging cycle immediately starts.

3.5. Charge Control

Managed object `batteryChargingOperState` indicates the current operational charging state of a battery and is a read-only object. For controlling the charging state, object `batteryChargingAdminState` can be used. Writing to this object initiates a request to adapt the operational state according to the value that has been written.

By default, the `batteryChargingAdminState` object is set to `notSet(1)`. In this state, the charging controller is using its predefined policies to decide which operational state is suitable in the current situation.

Setting the value of object `batteryChargingAdminState` may result in not changing the state of the battery to this value or even in setting the charging state to another value than the requested one. Due to operational conditions and limitations of the implementation of the Battery MIB module, changing the battery status according to a set value of object `batteryChargingAdminState` might not be possible.

For example, the charging controller might, at any time, decide to enter state `discharging(5)`, if there is an operational need to use the battery for supplying power.

The object `batteryChargingAdminState` will not automatically change when the object `batteryChargingOperState` changes. If the operational state is changed, e.g., to the state `discharging(5)` due to operational conditions, the admin state will remain in its current state. The charging controller SHOULD change the operational state to the state indicated by the object `batteryChargingAdminState` as soon as operational conditions allow this change.

If a state change of the object `batteryChargingAdminState` is desired upon change of the operational state, the object `batteryChargingOperState` must be polled or the notification `batteryChargingStateNotification` must be used to get notified about the state change. This could be used, e.g., if maintaining charge is not desired after fully charging a battery even if the charging controller and battery support it. The object `batteryChargingAdminState` can then be set to `doNotCharge(3)` when the object `batteryChargingOperState` changes from `charging(2)` to `maintainingCharge(3)`. Another use case would be when performing several charge and discharge cycles for battery maintenance.

3.6. Imported Definitions

The BATTERY-MIB module defined in this document imports definitions from the following MIB modules: `SNMPv2-SMI` [RFC2578], `SNMPv2-TC` [RFC2579], `SNMPv2-CONF` [RFC2580], `SNMP-FRAMEWORK-MIB` [RFC3411], and `ENTITY-MIB` [RFC6933].

4. Definitions

```
BATTERY-MIB DEFINITIONS ::= BEGIN
```

```
IMPORTS
```

```
  MODULE-IDENTITY, OBJECT-TYPE, NOTIFICATION-TYPE,
  mib-2, Integer32, Unsigned32
    FROM SNMPv2-SMI -- RFC 2578
  DateAndTime
    FROM SNMPv2-TC -- RFC 2579
  MODULE-COMPLIANCE, OBJECT-GROUP, NOTIFICATION-GROUP
    FROM SNMPv2-CONF -- RFC 2580
  SnmpAdminString
    FROM SNMP-FRAMEWORK-MIB -- RFC 3411
  entPhysicalIndex
    FROM ENTITY-MIB; -- RFC 6933
```

batteryMIB MODULE-IDENTITY

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DESCRIPTION

"This MIB module defines a set of objects for monitoring batteries of networked devices and of their components.

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This version of this MIB module is part of RFC 7577; see the RFC itself for full legal notices."

-- Revision history

REVISION "201506150000Z" -- 15 June 2015
DESCRIPTION

"Initial version published as RFC 7577."

::= { mib-2 233 }

```

--*****
-- Top-Level Structure of the MIB Module
--*****

batteryNotifications OBJECT IDENTIFIER ::= { batteryMIB 0 }
batteryObjects       OBJECT IDENTIFIER ::= { batteryMIB 1 }
batteryConformance  OBJECT IDENTIFIER ::= { batteryMIB 2 }

=====
-- 1. Object Definitions
=====

-----
-- 1.1. Battery Table
-----

batteryTable OBJECT-TYPE
    SYNTAX      SEQUENCE OF BatteryEntry
    MAX-ACCESS  not-accessible
    STATUS      current
    DESCRIPTION
        "This table provides information on batteries. It contains
        one conceptual row per battery in a managed entity.

        Batteries are indexed by the entPhysicalIndex of the
        entPhysicalTable defined in the ENTITY-MIB (RFC 6933).

        For implementations of the BATTERY-MIB, an implementation of
        the ENTITY-MIB complying with the entity4CRCompliance
        MODULE-COMPLIANCE statement of the ENTITY-MIB is required.

        If batteries are replaced, and the replacing battery uses
        the same physical connector as the replaced battery, then
        the replacing battery SHOULD be indexed with the same value
        of object entPhysicalIndex as the replaced battery."
    ::= { batteryObjects 1 }

batteryEntry OBJECT-TYPE
    SYNTAX      BatteryEntry
    MAX-ACCESS  not-accessible
    STATUS      current
    DESCRIPTION
        "An entry providing information on a battery."
    INDEX      { entPhysicalIndex }
    ::= { batteryTable 1 }

```

```

BatteryEntry ::=
  SEQUENCE {
    batteryIdentifier          SnmpAdminString,
    batteryFirmwareVersion    SnmpAdminString,
    batteryType                INTEGER,
    batteryTechnology          Unsigned32,
    batteryDesignVoltage      Unsigned32,
    batteryNumberOfCells      Unsigned32,
    batteryDesignCapacity     Unsigned32,
    batteryMaxChargingCurrent Unsigned32,
    batteryTrickleChargingCurrent Unsigned32,
    batteryActualCapacity     Unsigned32,
    batteryChargingCycleCount Unsigned32,
    batteryLastChargingCycleTime DateAndTime,
    batteryChargingOperState  INTEGER,
    batteryChargingAdminState INTEGER,
    batteryActualCharge       Unsigned32,
    batteryActualVoltage      Unsigned32,
    batteryActualCurrent      Integer32,
    batteryTemperature        Integer32,
    batteryAlarmLowCharge     Unsigned32,
    batteryAlarmLowVoltage    Unsigned32,
    batteryAlarmLowCapacity   Unsigned32,
    batteryAlarmHighCycleCount Unsigned32,
    batteryAlarmHighTemperature Integer32,
    batteryAlarmLowTemperature Integer32,
    batteryCellIdentifier     SnmpAdminString
  }

```

```

batteryIdentifier OBJECT-TYPE
  SYNTAX      SnmpAdminString
  MAX-ACCESS  read-only
  STATUS      current
  DESCRIPTION

```

"This object contains an identifier for the battery.

Many manufacturers deliver not only simple batteries but battery packages including additional hardware and firmware. Typically, these modules include an identifier that can be retrieved by a device in which a battery has been installed. The identifier is useful when batteries are removed and reinstalled in the same or other devices. Then, the device or the network management system can trace batteries and achieve continuity of battery monitoring.

If the battery is identified by more than one value, for example, by a model number and a serial number, then the value of this object is a concatenation of these

values, separated by the colon symbol ':'. The values should be ordered so that a more significant value comes before a less significant one. In the example above, the (more significant) model number would be first, and the serial number would follow: '<model number>:<serial number>'.

If the battery identifier cannot be represented using the ISO/IEC IS 10646-1 character set, then a hexadecimal encoding of a binary representation of the entire battery identifier must be used.

The value of this object must be an empty string if there is no battery identifier or if the battery identifier is unknown."

```
::= { batteryEntry 1 }
```

batteryFirmwareVersion OBJECT-TYPE

SYNTAX SnmpAdminString

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object indicates the version number of the firmware that is included in a battery module.

Many manufacturers deliver not pure batteries but battery packages including additional hardware and firmware.

Since the behavior of the battery may change with the firmware, it may be useful to retrieve the firmware version number.

The value of this object must be an empty string if there is no firmware or if the version number of the firmware is unknown."

```
::= { batteryEntry 2 }
```

batteryType OBJECT-TYPE

SYNTAX INTEGER {
 unknown(1),
 other(2),
 primary(3),
 rechargeable(4),
 capacitor(5)
 }

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object indicates the type of battery.

It distinguishes between primary (not rechargeable) batteries, rechargeable (secondary) batteries, and capacitors. Capacitors are not really batteries but are often used in the same way as a battery.

The value other(2) can be used if the battery type is known but is none of the ones above. Value unknown(1) is to be used if the type of battery cannot be determined."

```
::= { batteryEntry 3 }
```

batteryTechnology OBJECT-TYPE

SYNTAX Unsigned32

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object indicates the technology used by the battery. Numbers identifying battery technologies are registered at IANA. A current list of assignments can be found at <<http://www.iana.org/assignments/battery-technologies>>.

Value unknown(1) MUST be used if the technology of the battery cannot be determined.

Value other(2) can be used if the battery technology is known but is not one of the types already registered at IANA."

```
::= { batteryEntry 4 }
```

batteryDesignVoltage OBJECT-TYPE

SYNTAX Unsigned32

UNITS "millivolt"

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object provides the design (or nominal) voltage of the battery in units of millivolt (mV).

Note that the design voltage is a constant value and typically different from the actual voltage of the battery.

A value of 0 indicates that the design voltage is unknown."

```
::= { batteryEntry 5 }
```

batteryNumberOfCells OBJECT-TYPE

SYNTAX Unsigned32

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object indicates the number of cells contained in the battery.

A value of 0 indicates that the number of cells is unknown."

::= { batteryEntry 6 }

batteryDesignCapacity OBJECT-TYPE

SYNTAX Unsigned32

UNITS "milliampere hours"

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object provides the design (or nominal) capacity of the battery in units of milliampere hours (mAh).

Note that the design capacity is a constant value and typically different from the actual capacity of the battery. Usually, this is a value provided by the manufacturer of the battery.

A value of 0 indicates that the design capacity is unknown."

::= { batteryEntry 7 }

batteryMaxChargingCurrent OBJECT-TYPE

SYNTAX Unsigned32

UNITS "milliampere"

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object provides the maximum current to be used for charging the battery in units of milliampere (mA).

Note that the maximum charging current may not lead to optimal charge of the battery and that some batteries can only be charged with the maximum current for a limited amount of time.

A value of 0 indicates that the maximum charging current is unknown."

::= { batteryEntry 8 }

batteryTrickleChargingCurrent OBJECT-TYPE

SYNTAX Unsigned32

UNITS "milliampere"

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object provides the recommended average current to be used for trickle charging the battery in units of mA.

Typically, this is a value recommended by the manufacturer of the battery or by the manufacturer of the charging circuit.

A value of 0 indicates that the recommended trickle charging current is unknown."

::= { batteryEntry 9 }

batteryActualCapacity OBJECT-TYPE

SYNTAX Unsigned32
UNITS "milliampere hours"
MAX-ACCESS read-only
STATUS current

DESCRIPTION

"This object provides the actual capacity of the battery in units of mAh.

Typically, the actual capacity of a battery decreases with time and with usage of the battery. It is usually lower than the design capacity.

Note that the actual capacity needs to be measured and is typically an estimate based on observed discharging and charging cycles of the battery.

A value of 'ffffffff'H indicates that the actual capacity cannot be determined."

::= { batteryEntry 10 }

batteryChargingCycleCount OBJECT-TYPE

SYNTAX Unsigned32
MAX-ACCESS read-only
STATUS current

DESCRIPTION

"This object indicates the number of completed charging cycles that the battery underwent. In line with the Smart Battery Data Specification Revision 1.1, a charging cycle is defined as the process of discharging the battery by a total amount equal to the battery design capacity as given by object batteryDesignCapacity. A charging cycle may include several steps of charging and discharging the battery until the discharging amount given by batteryDesignCapacity has been reached. As soon as a

charging cycle has been completed, the next one starts immediately, independent of the battery's current charge at the end of the cycle.

For batteries of type primary(3), the value of this object is always 0.

A value of 'ffffffff'H indicates that the number of charging cycles cannot be determined."

::= { batteryEntry 11 }

batteryLastChargingCycleTime OBJECT-TYPE

SYNTAX DateAndTime

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"The date and time of the last charging cycle. The value '0000000000000000'H is returned if the battery has not been charged yet or if the last charging time cannot be determined.

For batteries of type primary(1), the value of this object is always '0000000000000000'H."

::= { batteryEntry 12 }

batteryChargingOperState OBJECT-TYPE

SYNTAX INTEGER {
 unknown(1),
 charging(2),
 maintainingCharge(3),
 noCharging(4),
 discharging(5)
 }

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object indicates the current charging state of the battery.

Value unknown(1) indicates that the charging state of the battery cannot be determined.

Value charging(2) indicates that the battery is being charged in a way such that the charge of the battery increases.

Value maintainingCharge(3) indicates that the battery is being charged with a low-average current that compensates

self-discharging. This includes trickle charging, float charging, and other methods for maintaining the current charge of a battery. In typical implementations of charging controllers, state maintainingCharge(3) is only applied if the battery is fully charged or almost fully charged.

Value noCharging(4) indicates that the battery is not being charged or discharged by electric current between the battery and electric circuits external to the battery. Note that the battery may still be subject to self-discharging.

Value discharging(5) indicates that the battery is either used as the power source for electric circuits external to the battery or discharged intentionally by the charging controller, e.g., for the purpose of battery maintenance. In any case, the charge of the battery decreases."

```
::= { batteryEntry 13 }
```

batteryChargingAdminState OBJECT-TYPE

```
SYNTAX      INTEGER {
                notSet(1),
                charge(2),
                doNotCharge(3),
                discharge(4)
            }
```

MAX-ACCESS read-write

STATUS current

DESCRIPTION

"The value of this object indicates the desired charging state of the battery. The real state is indicated by object batteryChargingOperState. See the definition of object batteryChargingOperState for a description of the values.

When this object is initialized by an implementation of the BATTERY-MIB module, its value is set to notSet(1). In this case, the charging controller is free to choose which operational state is suitable.

When the batteryChargingAdminState object is set, then the BATTERY-MIB implementation must try to set the battery to the indicated state. The result will be indicated by object batteryChargingOperState.

Setting object batteryChargingAdminState to value notSet(1) is a request to the charging controller to operate

autonomously and choose the operational state that is suitable.

Setting object `batteryChargingAdminState` to value `charge(2)` is a request to enter the operational state `charging(2)` until the battery is fully charged. When the battery is fully charged, or if the battery was already fully charged or almost fully charged at the time of the request, the operational state will change to `maintainingCharge(3)` if the charging controller and the battery support the functionality of maintaining the charge, or it will change to `noCharging(4)` otherwise.

Setting object `batteryChargingAdminState` to value `doNotCharge(3)` is a request for entering operational state `noCharging(4)`.

Setting object `batteryChargingAdminState` to value `discharge(4)` is a request for entering operational state `discharging(5)`. Discharging can be accomplished by ordinary use, applying a dedicated load, or any other means. An example for applying this state is battery maintenance. If the battery is empty or almost empty, the operational state will change to `noCharging(4)`. The charging controller will decide which charge condition will be considered empty dependent on the battery technology used. This is done to avoid damage on the battery due to deep discharge.

Due to operational conditions and limitations of the implementation of the BATTERY-MIB module, changing the battery status according to a set value of object `batteryChargingAdminState` may not be possible. Setting the value of object `batteryChargingAdminState` may result in not changing the state of the battery to this value or even in setting the charging state to another value than the requested one. For example, the charging controller might at any time decide to enter state `discharging(5)`, if there is an operational need to use the battery for supplying power."

```
::= { batteryEntry 14 }
```

```
batteryActualCharge OBJECT-TYPE
    SYNTAX      Unsigned32
    UNITS       "milliampere hours"
    MAX-ACCESS  read-only
    STATUS      current
```

DESCRIPTION

"This object provides the actual charge of the battery in units of mAh.

Note that the actual charge needs to be measured and is typically an estimate based on observed discharging and charging cycles of the battery.

A value of 'ffffffff'H indicates that the actual charge cannot be determined."

::= { batteryEntry 15 }

batteryActualVoltage OBJECT-TYPE

SYNTAX Unsigned32

UNITS "millivolt"

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object provides the actual voltage of the battery in units of mV.

A value of 'ffffffff'H indicates that the actual voltage cannot be determined."

::= { batteryEntry 16 }

batteryActualCurrent OBJECT-TYPE

SYNTAX Integer32

UNITS "milliampere"

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object provides the actual charging or discharging current of the battery in units of mA.

The charging current is represented by positive values, and the discharging current is represented by negative values.

A value of '7fffffff'H indicates that the actual current cannot be determined."

::= { batteryEntry 17 }

batteryTemperature OBJECT-TYPE

SYNTAX Integer32

UNITS "deci-degrees Celsius"

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"The ambient temperature at or within close proximity of the battery.

A value of '7fffffff'H indicates that the temperature cannot be determined."

::= { batteryEntry 18 }

batteryAlarmLowCharge OBJECT-TYPE

SYNTAX Unsigned32
UNITS "milliampere hours"
MAX-ACCESS read-write
STATUS current

DESCRIPTION

"This object provides the lower-threshold value for object batteryActualCharge. If the value of object batteryActualCharge falls below this threshold, a low-battery alarm will be raised. The alarm procedure may include generating a batteryLowNotification.

This object should be set to a value such that when the batteryLowNotification is generated, the battery is still sufficiently charged to keep the device(s) that it powers operational for a time long enough to take actions before the powered device(s) enters a 'sleep' or 'off' state.

A value of 0 indicates that no alarm will be raised for any value of object batteryActualVoltage."

::= { batteryEntry 19 }

batteryAlarmLowVoltage OBJECT-TYPE

SYNTAX Unsigned32
UNITS "millivolt"
MAX-ACCESS read-write
STATUS current

DESCRIPTION

"This object provides the lower-threshold value for object batteryActualVoltage. If the value of object batteryActualVoltage falls below this threshold, a low-battery alarm will be raised. The alarm procedure may include generating a batteryLowNotification.

This object should be set to a value such that when the batteryLowNotification is generated, the battery is still sufficiently charged to keep the device(s) that it powers operational for a time long enough to take actions before the powered device(s) enters a 'sleep' or 'off' state.

A value of 0 indicates that no alarm will be raised for any value of object batteryActualVoltage."

::= { batteryEntry 20 }

batteryAlarmLowCapacity OBJECT-TYPE

SYNTAX Unsigned32
UNITS "milliampere hours"
MAX-ACCESS read-write
STATUS current

DESCRIPTION

"This object provides the lower-threshold value for object batteryActualCapacity. If the value of object batteryActualCapacity falls below this threshold, a battery aging alarm will be raised. The alarm procedure may include generating a batteryAgingNotification.

A value of 0 indicates that no alarm will be raised for any value of object batteryActualCapacity."

::= { batteryEntry 21 }

batteryAlarmHighCycleCount OBJECT-TYPE

SYNTAX Unsigned32
MAX-ACCESS read-write
STATUS current

DESCRIPTION

"This object provides the upper-threshold value for object batteryChargingCycleCount. If the value of object batteryChargingCycleCount rises above this threshold, a battery aging alarm will be raised. The alarm procedure may include generating a batteryAgingNotification.

A value of 0 indicates that no alarm will be raised for any value of object batteryChargingCycleCount."

::= { batteryEntry 22 }

batteryAlarmHighTemperature OBJECT-TYPE

SYNTAX Integer32
UNITS "deci-degrees Celsius"
MAX-ACCESS read-write
STATUS current

DESCRIPTION

"This object provides the upper-threshold value for object batteryTemperature. If the value of object batteryTemperature rises above this threshold, a battery high temperature alarm will be raised. The alarm procedure may include generating a batteryTemperatureNotification.

A value of '7fffffff'H indicates that no alarm will be raised for any value of object batteryTemperature."

::= { batteryEntry 23 }

batteryAlarmLowTemperature OBJECT-TYPE

SYNTAX Integer32
UNITS "deci-degrees Celsius"
MAX-ACCESS read-write
STATUS current

DESCRIPTION

"This object provides the lower-threshold value for object batteryTemperature. If the value of object batteryTemperature falls below this threshold, a battery low temperature alarm will be raised. The alarm procedure may include generating a batteryTemperatureNotification.

A value of '7fffffff'H indicates that no alarm will be raised for any value of object batteryTemperature."

::= { batteryEntry 24 }

batteryCellIdentifier OBJECT-TYPE

SYNTAX SnmpAdminString
MAX-ACCESS read-only
STATUS current

DESCRIPTION

"The value of this object identifies one or more cells of a battery. The format of the cell identifier may vary between different implementations. It should uniquely identify one or more cells of the indexed battery.

This object can be used for batteries, such as lithium polymer batteries for which battery controllers monitor cells individually.

This object is used by notifications of types batteryLowNotification, batteryTemperatureNotification, batteryCriticalNotification, and batteryAgingNotification. These notifications can use the value of this object to indicate the event that triggered the generation of the notification in more detail by specifying a single cell or a set of cells within the battery that is specifically addressed by the notification.

An example use case for this object is a single cell in a battery that exceeds the temperature indicated by object batteryAlarmHighTemperature. In such a case, a batteryTemperatureNotification can be generated that not only indicates the battery for which the temperature limit has been exceeded but also the particular cell.

The initial value of this object is the empty string. The value of this object is set each time a

batteryLowNotification, batteryTemperatureNotification, batteryCriticalNotification, or batteryAgingNotification is generated.

When a notification is generated that does not indicate a specific cell or set of cells, the value of this object is set to the empty string."

```
::= { batteryEntry 25 }
```

```
-----
-- 2. Notifications
-----
```

```
batteryChargingStateNotification NOTIFICATION-TYPE
```

```
  OBJECTS      {
    batteryChargingOperState
  }
```

```
  STATUS      current
```

```
  DESCRIPTION
```

"This notification can be generated when a charging state of the battery (indicated by the value of object batteryChargingOperState) is triggered by an event other than a write action to object batteryChargingAdminState. Such an event may, for example, be triggered by a local battery controller."

```
::= { batteryNotifications 1 }
```

```
batteryLowNotification NOTIFICATION-TYPE
```

```
  OBJECTS      {
    batteryActualCharge,
    batteryActualVoltage,
    batteryCellIdentifier
  }
```

```
  STATUS      current
```

```
  DESCRIPTION
```

"This notification can be generated when the current charge (batteryActualCharge) or the current voltage (batteryActualVoltage) of the battery falls below a threshold defined by object batteryAlarmLowCharge or object batteryAlarmLowVoltage, respectively.

Note that, typically, this notification is generated in a state where the battery is still sufficiently charged to keep the device(s) that it powers operational for some time. If the charging state of the battery has become critical, i.e., the device(s) powered by the battery must go to a 'sleep' or 'off' state, then the batteryCriticalNotification should be used instead.

If the low charge or voltage has been detected for a single cell or a set of cells of the battery and not for the entire battery, then object `batteryCellIdentifier` should be set to a value that identifies the cell or set of cells. Otherwise, the value of object `batteryCellIdentifier` should be set to the empty string when this notification is generated.

The notification should not be sent again for the same battery or cell before either (a) the current voltage or the current charge, respectively, has become higher than the corresponding threshold through charging or (b) an indication of a maintenance action has been detected, such as a battery disconnection event or a reinitialization of the battery monitoring system.

This notification should not be sent when the battery is in a charging mode, i.e., the value of object `batteryChargingOperState` is `charging(2)`."

```
::= { batteryNotifications 2 }
```

```
batteryCriticalNotification NOTIFICATION-TYPE
```

```
OBJECTS {
    batteryActualCharge,
    batteryActualVoltage,
    batteryCellIdentifier
}
```

```
STATUS current
```

```
DESCRIPTION
```

"This notification can be generated when the current charge of the battery falls so low that it cannot provide a sufficient power supply function for regular operation of the powered device(s). The battery needs to be charged before it can be used for regular power supply again. The battery may still provide sufficient power for a 'sleep' mode of a powered device(s) or for a transition into an 'off' mode.

If the critical state is caused by a single cell or a set of cells of the battery, then object `batteryCellIdentifier` should be set to a value that identifies the cell or set of cells. Otherwise, the value of object `batteryCellIdentifier` should be set to the empty string when this notification is generated.

The notification should not be sent again for the same battery before either the battery charge has increased through charging to a non-critical value or an indication

of a maintenance action has been detected, such as a battery disconnection event or a reinitialization of the battery monitoring system.

This notification should not be sent when the battery is in a charging mode, i.e., the value of object `batteryChargingOperState` is `charging(2)`."

```
::= { batteryNotifications 3 }
```

`batteryTemperatureNotification` NOTIFICATION-TYPE

```
OBJECTS      {
    batteryTemperature,
    batteryCellIdentifier
}
```

```
STATUS      current
```

```
DESCRIPTION
```

"This notification can be generated when the measured temperature (`batteryTemperature`) rises above the threshold defined by object `batteryAlarmHighTemperature` or falls below the threshold defined by object `batteryAlarmLowTemperature`.

If the low or high temperature has been detected for a single cell or a set of cells of the battery and not for the entire battery, then object `batteryCellIdentifier` should be set to a value that identifies the cell or set of cells. Otherwise, the value of object `batteryCellIdentifier` should be set to the empty string when this notification is generated.

It may occur that the temperature alternates between values slightly below and slightly above a threshold. For limiting the notification rate in such a case, this notification should not be sent again for the same battery or cell, respectively, within a time interval of 10 minutes.

An exception to the rate limitations occurs immediately after the reinitialization of the battery monitoring system. At this point in time, if the battery temperature is above the threshold defined by object `batteryAlarmHighTemperature` or below the threshold defined by object `batteryAlarmLowTemperature`, respectively, then this notification should be sent, independent of the time at which previous notifications for the same battery or cell, respectively, had been sent."

```
::= { batteryNotifications 4 }
```

batteryAgingNotification NOTIFICATION-TYPE

```
OBJECTS      {
    batteryActualCapacity,
    batteryChargingCycleCount,
    batteryCellIdentifier
}
```

```
STATUS      current
```

DESCRIPTION

"This notification can be generated when the actual capacity (batteryActualCapacity) falls below a threshold defined by object batteryAlarmLowCapacity or when the charging cycle count of the battery (batteryChargingCycleCount) exceeds the threshold defined by object batteryAlarmHighCycleCount.

If the aging has been detected for a single cell or a set of cells of the battery and not for the entire battery, then object batteryCellIdentifier should be set to a value that identifies the cell or set of cells. Otherwise, the value of object batteryCellIdentifier should be set to the empty string when this notification is generated.

This notification should not be sent again for the same battery or cell, respectively, before an indication of a maintenance action has been detected, such as a battery disconnection event or a reinitialization of the battery monitoring system."

```
::= { batteryNotifications 5 }
```

batteryConnectedNotification NOTIFICATION-TYPE

```
OBJECTS      {
    batteryIdentifier
}
```

```
STATUS      current
```

DESCRIPTION

"This notification can be generated when it has been detected that a battery has been connected. The battery can be identified by the value of object batteryIdentifier as well as by the value of index entPhysicalIndex that is contained in the OID of object batteryIdentifier."

```
::= { batteryNotifications 6 }
```

batteryDisconnectedNotification NOTIFICATION-TYPE

```
STATUS      current
```

DESCRIPTION

"This notification can be generated when it has been detected that one or more batteries have been disconnected."

```
::= { batteryNotifications 7 }
```

```

=====
-- 3. Conformance Information
=====

batteryCompliances OBJECT IDENTIFIER ::= { batteryConformance 1 }
batteryGroups       OBJECT IDENTIFIER ::= { batteryConformance 2 }

-----

-- 3.1. Compliance Statements
-----

batteryCompliance MODULE-COMPLIANCE
    STATUS          current
    DESCRIPTION
        "The compliance statement for implementations of the
        BATTERY-MIB module.

        A compliant implementation MUST implement the objects
        defined in the mandatory groups batteryDescriptionGroup
        and batteryStatusGroup.

        Note that this compliance statement requires
        compliance with the entity4CRCompliance
        MODULE-COMPLIANCE statement of the
        ENTITY-MIB (RFC 6933)."
```

MODULE -- this module

```

    MANDATORY-GROUPS {
        batteryDescriptionGroup,
        batteryStatusGroup
    }

    GROUP batteryAlarmThresholdsGroup
    DESCRIPTION
        "A compliant implementation does not have to implement
        the batteryAlarmThresholdsGroup."

    GROUP batteryNotificationsGroup
    DESCRIPTION
        "A compliant implementation does not have to implement
        the batteryNotificationsGroup."

    GROUP batteryPerCellNotificationsGroup
    DESCRIPTION
        "A compliant implementation does not have to implement
        the batteryPerCellNotificationsGroup."

    GROUP batteryAdminGroup
    DESCRIPTION
```

"A compliant implementation does not have to implement the batteryAdminGroup."

OBJECT batteryAlarmLowCharge
 MIN-ACCESS read-only
 DESCRIPTION
 "A compliant implementation is not required to support set operations on this object."

OBJECT batteryAlarmLowVoltage
 MIN-ACCESS read-only
 DESCRIPTION
 "A compliant implementation is not required to support set operations on this object."

OBJECT batteryAlarmLowCapacity
 MIN-ACCESS read-only
 DESCRIPTION
 "A compliant implementation is not required to support set operations on this object."

OBJECT batteryAlarmHighCycleCount
 MIN-ACCESS read-only
 DESCRIPTION
 "A compliant implementation is not required to support set operations on this object."

OBJECT batteryAlarmHighTemperature
 MIN-ACCESS read-only
 DESCRIPTION
 "A compliant implementation is not required to support set operations on this object."

OBJECT batteryAlarmLowTemperature
 MIN-ACCESS read-only
 DESCRIPTION
 "A compliant implementation is not required to support set operations on this object."

::= { batteryCompliances 1 }

 -- 3.2. MIB Grouping

batteryDescriptionGroup OBJECT-GROUP
 OBJECTS {
 batteryIdentifier,

```
        batteryFirmwareVersion,
        batteryType,
        batteryTechnology,
        batteryDesignVoltage,
        batteryNumberOfCells,
        batteryDesignCapacity,
        batteryMaxChargingCurrent,
        batteryTrickleChargingCurrent
    }
    STATUS          current
    DESCRIPTION
        "A compliant implementation MUST implement the objects
        contained in this group."
    ::= { batteryGroups 1 }

batteryStatusGroup OBJECT-GROUP
    OBJECTS {
        batteryActualCapacity,
        batteryChargingCycleCount,
        batteryLastChargingCycleTime,
        batteryChargingOperState,
        batteryActualCharge,
        batteryActualVoltage,
        batteryActualCurrent,
        batteryTemperature
    }
    STATUS          current
    DESCRIPTION
        "A compliant implementation MUST implement the objects
        contained in this group."
    ::= { batteryGroups 2 }

batteryAdminGroup OBJECT-GROUP
    OBJECTS {
        batteryChargingAdminState
    }
    STATUS          current
    DESCRIPTION
        "A compliant implementation does not have to implement the
        object contained in this group."
    ::= { batteryGroups 3 }

batteryAlarmThresholdsGroup OBJECT-GROUP
    OBJECTS {
        batteryAlarmLowCharge,
        batteryAlarmLowVoltage,
        batteryAlarmLowCapacity,
        batteryAlarmHighCycleCount,
```



```

        batteryAlarmHighTemperature,
        batteryAlarmLowTemperature
    }
    STATUS          current
    DESCRIPTION
        "A compliant implementation does not have to implement the
        objects contained in this group."
    ::= { batteryGroups 4 }

batteryNotificationsGroup NOTIFICATION-GROUP
    NOTIFICATIONS {
        batteryChargingStateNotification,
        batteryLowNotification,
        batteryCriticalNotification,
        batteryAgingNotification,
        batteryTemperatureNotification,
        batteryConnectedNotification,
        batteryDisconnectedNotification
    }
    STATUS          current
    DESCRIPTION
        "A compliant implementation does not have to implement the
        notifications contained in this group."
    ::= { batteryGroups 5 }

batteryPerCellNotificationsGroup OBJECT-GROUP
    OBJECTS {
        batteryCellIdentifier
    }
    STATUS          current
    DESCRIPTION
        "A compliant implementation does not have to implement the
        object contained in this group."
    ::= { batteryGroups 6 }
END

```

5. Security Considerations

There are a number of management objects defined in this MIB module with a MAX-ACCESS clause of read-write. 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 opens devices to attack. These are the tables and objects and their sensitivity/vulnerability:

- o batteryChargingAdminState:
Setting the battery charging state can be beneficial for an operator for various reasons such as charging batteries when the

price of electricity is low. However, setting the charging state can be used by an attacker to discharge batteries of devices and thereby switching these devices off if they are powered solely by batteries. In particular, if the `batteryAlarmLowCharge` and `batteryAlarmLowVoltage` can also be set, this attack will go unnoticed (i.e., no notifications are sent).

- o `batteryAlarmLowCharge` and `batteryAlarmLowVoltage`:
These objects set the threshold for an alarm to be raised when the battery charge or voltage falls below the corresponding one of them. An attacker setting one of these alarm values can switch off the alarm by setting it to the 'off' value 0, or it can modify the alarm behavior by setting it to any other value. The result may be loss of data if the battery runs empty without warning to a recipient expecting such a notification.
- o `batteryAlarmLowCapacity` and `batteryAlarmHighCycleCount`:
These objects set the threshold for an alarm to be raised when the battery becomes older and less performant than required for stable operation. An attacker setting this alarm value can switch off the alarm by setting it to the 'off' value 0 or modify the alarm behavior by setting it to any other value. This may lead to either a costly replacement of a working battery or use of batteries that are too old or too weak. The consequence of the latter could be that, e.g., a battery cannot provide power long enough between two scheduled charging actions causing the powered device to shut down and potentially lose data.
- o `batteryAlarmHighTemperature` and `batteryAlarmLowTemperature`:
These objects set thresholds for an alarm to be raised when the battery rises above / falls below them. An attacker setting one of these alarm values can switch off these alarms by setting them to the 'off' value '7fffffff'H, or it can modify the alarm behavior by setting them to any other value. The result may be, e.g., an unnecessary shutdown of a device if `batteryAlarmHighTemperature` is set too low, there is damage to the device by temperatures that are too high if switched off or set to values that are too high, or there is damage to the battery when, e.g., it is being charged. Batteries can also be damaged, e.g., in an attempt to charge them at temperatures that are too low.

Some of the readable objects in this MIB module (i.e., objects with a `MAX-ACCESS` other than `not-accessible`) may be considered sensitive or vulnerable in some network environments. It is thus important to control even `GET` and/or `NOTIFY` access to these objects and possibly to even encrypt the values of these objects when sending them over the network via `SNMP`. These are the tables and objects and their sensitivity/vulnerability:

All potentially sensible or vulnerable objects of this MIB module are in the batteryTable. In general, there are no serious operational vulnerabilities foreseen in case of an unauthorized read access to this table. However, corporate confidentiality issues need to be considered. The following information or parts of it might be a trade secret:

- o the number of batteries installed in a managed node (batteryIndex)
- o properties of these batteries (batteryActualCapacity and batteryChargingCycleCount)
- o the time at which the next replacement cycle for batteries can be expected (batteryAlarmLowCapacity and batteryAlarmHighCycleCount)
- o the types of batteries in use and their firmware versions (batteryIdentifier, batteryFirmwareVersion, batteryType, and batteryTechnology)

For any battery-powered device whose use can be correlated to an individual or a small group of individuals, the following objects have the potential to reveal information about those individuals' activities or habits (e.g., if they are near a power outlet, if they have been using their devices heavily, etc.):

- o batteryChargingCycleCount
- o batteryLastChargingCycleTime
- o batteryChargingOperState
- o batteryActualCharge
- o batteryActualVoltage
- o batteryActualCurrent
- o batteryTemperature
- o batteryAlarmLowCharge
- o batteryAlarmLowVoltage
- o batteryAlarmLowCapacity
- o batteryAlarmHighCycleCount
- o batteryAlarmHighTemperature

- o batteryAlarmLowTemperature

Implementers of this specification should use appropriate privacy protections as discussed in Section 9 of "Requirements for Energy Management" [RFC6988]. Battery monitoring of devices used by individuals or in homes should only occur with proper authorization.

SNMP versions prior to SNMPv3 did not include adequate security. 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.

Implementations SHOULD provide the security features described by the SNMPv3 framework (see [RFC3410]), and implementations claiming compliance to the SNMPv3 standard MUST include full support for authentication and privacy via the User-based Security Model (USM) [RFC3414] with the AES cipher algorithm [RFC3826]. Implementations MAY also provide support for the Transport Security Model (TSM) [RFC5591] in combination with a secure transport such as SSH [RFC5592] or TLS/DTLS [RFC6353].

Further, deployment of SNMP versions prior to SNMPv3 is NOT RECOMMENDED. Instead, it is RECOMMENDED to deploy SNMPv3 and to enable cryptographic security. It is then a customer/operator responsibility to ensure that the SNMP entity giving access to an instance of this MIB module 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. IANA Considerations

6.1. SMI Object Identifier Registration

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

Descriptor	OBJECT IDENTIFIER value
-----	-----
batteryMIB	{ mib-2 233 }

6.2. Battery Technology Registration

Object batteryTechnology defined in Section 4 reports battery technologies. Eighteen values for battery technologies have initially been defined. They are listed in a table in Section 3.2.

For ensuring extensibility of this list, IANA has created a registry for battery technologies at <http://www.iana.org/assignments/battery-technologies> and filled it with the initial list given in Section 3.2.

New assignments of numbers for battery technologies will be administered by IANA through Expert Review [RFC5226]. Experts must check for sufficient relevance of a battery technology to be added according to the guidelines in Section 3.2.1.

7. References

7.1. 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>.
- [RFC3411] Harrington, D., Presuhn, R., and B. Wijnen, "An Architecture for Describing Simple Network Management Protocol (SNMP) Management Frameworks", STD 62, RFC 3411, DOI 10.17487/RFC3411, December 2002, <http://www.rfc-editor.org/info/rfc3411>.
- [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>.

- [RFC3826] Blumenthal, U., Maino, F., and K. McCloghrie, "The Advanced Encryption Standard (AES) Cipher Algorithm in the SNMP User-based Security Model", RFC 3826, DOI 10.17487/RFC3826, June 2004, <<http://www.rfc-editor.org/info/rfc3826>>.
- [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>>.
- [RFC5591] Harrington, D. and W. Hardaker, "Transport Security Model for the Simple Network Management Protocol (SNMP)", STD 78, RFC 5591, DOI 10.17487/RFC5591, June 2009, <<http://www.rfc-editor.org/info/rfc5591>>.
- [RFC5592] Harrington, D., Salowey, J., and W. Hardaker, "Secure Shell Transport Model for the Simple Network Management Protocol (SNMP)", RFC 5592, DOI 10.17487/RFC5592, June 2009, <<http://www.rfc-editor.org/info/rfc5592>>.
- [RFC6353] Hardaker, W., "Transport Layer Security (TLS) Transport Model for the Simple Network Management Protocol (SNMP)", STD 78, RFC 6353, DOI 10.17487/RFC6353, July 2011, <<http://www.rfc-editor.org/info/rfc6353>>.
- [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>>.

7.2. Informative References

- [RFC1628] Case, J., Ed., "UPS Management Information Base", RFC 1628, DOI 10.17487/RFC1628, May 1994, <<http://www.rfc-editor.org/info/rfc1628>>.
- [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>>.
- [RFC6988] Quittek, J., Ed., Chandramouli, M., Winter, R., Dietz, T., and B. Claise, "Requirements for Energy Management", RFC 6988, DOI 10.17487/RFC6988, September 2013, <<http://www.rfc-editor.org/info/rfc6988>>.

- [RFC7326] Parello, J., Claise, B., Schoening, B., and J. Quittek, "Energy Management Framework", RFC 7326, DOI 10.17487/RFC7326, September 2014, <<http://www.rfc-editor.org/info/rfc7326>>.
- [RFC7460] Chandramouli, M., Claise, B., Schoening, B., Quittek, J., and T. Dietz, "Monitoring and Control MIB for Power and Energy", RFC 7460, DOI 10.17487/RFC7460, March 2015, <<http://www.rfc-editor.org/info/rfc7460>>.
- [SBS] "Smart Battery Data Specification", Revision 1.1, December 1998.

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