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Definition of Managed Objects for Battery Monitoring
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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.

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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 smart phones. 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 [I-D.ietf-eman-framework] it is an Energy Managed Object, and thus, MIB modules such as the Power and Energy Monitoring MIB [I-D.ietf-eman-energy-monitoring-mib] 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 re-charged),
- o last usage of a battery,
- o maximum energy provided by a battery (remaining and total capacity).

Further, means are provided for battery-powered devices to send notifications when the current battery charge has dropped below a certain threshold to inform the management system of needed replacement. 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 but no additional hardware instrumentation for battery monitoring.

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 e.g. installed in another device. The firmware version is useful information as the battery behavior might be different for different firmware versions.

Not explicitly in scope of definitions in this document are very small backup batteries, such as for example, batteries used on 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 an UPS system. However, the information provided by the UPS MIB objects is limited and tailored the particular needs of UPS systems.

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 of 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 batteries are replaced with the replacing battery using the same physical connector as the replaced battery had used, then the replacing battery SHOULD 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 1-10) provides information on static properties of the battery. The second group of objects (OIDs ending with 11-18) 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)
    +-- r-n SnmpAdminString  batteryCellIdentifier(19)
    +-- rwn Unsigned32       batteryAlarmLowCharge(20)
    +-- rwn Unsigned32       batteryAlarmLowVoltage(21)
    +-- rwn Unsigned32       batteryAlarmLowCapacity(22)
    +-- rwn Unsigned32       batteryAlarmHighCycleCount(23)
    +-- rwn Integer32        batteryAlarmHighTemperature(24)
    +-- rwn Integer32        batteryAlarmLowTemperature(25)

```

The third group of objects in this table (OIDs ending with 20-25) indicates thresholds which 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 that cannot be used anymore for power supply,
4. an aged battery that may need to be replaced,
5. a battery exceed a temperature threshold,
6. a battery that has been connected,
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 subject of intensive research and widely used technologies are often replaced by successor technologies within an 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/eman> where numbers are assigned to battery technologies (TBD).

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	assigned number
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
Nickel-cadmium	13
Nickel-metal hybride	14
Nickel-zinc	15
Lithium-ion	16
Lithium polymer	17
Double layer capacitor	18

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 one. 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 re-installed 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.

4. Definitions

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

```
IMPORTS
```

```
    MODULE-IDENTITY, OBJECT-TYPE, NOTIFICATION-TYPE,  
    mib-2, Integer32, Unsigned32
```



```
FROM SNMPv2-SMI -- RFC2578
SnmpAdminString
FROM SNMP-FRAMEWORK-MIB -- RFC3411
DateAndTime
FROM SNMPv2-TC -- RFC2579
MODULE-COMPLIANCE, OBJECT-GROUP, NOTIFICATION-GROUP
FROM SNMPv2-CONF -- RFC2580
entPhysicalIndex
FROM ENTITY-MIB -- RFC6933
Unsigned64TC
FROM APPLICATION-MIB; -- RFC2564

batteryMIB MODULE-IDENTITY
LAST-UPDATED "201401071200Z" -- 07 January 2014
ORGANIZATION "IETF EMAN Working Group"
CONTACT-INFO
    "General Discussion: eman@ietf.org
    To Subscribe: http://www.ietf.org/mailman/listinfo/eman
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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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    authors of the code. All rights reserved.

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    (http://trustee.ietf.org/license-info).

    This version of this MIB module is part of RFC yyyy; see
    the RFC itself for full legal notices."
-- replace yyyy with actual RFC number & remove this notice
```

```
-- Revision history

REVISION "201401071200Z"          -- 07 January 2014
DESCRIPTION
    "Initial version, published as RFC yyyy."
-- replace yyyy with actual RFC number & remove this notice

 ::= { mib-2 zzz }
-- zzz to be assigned by IANA.

--*****
-- 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.

        Batteries are indexed by the entPhysicalIndex of the
        entPhysicalTable defined in the ENTITY-MIB (RFC6933).

        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 with the replacing battery using
        the same physical connector as the replaced battery had
        used, 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        Unsigned64TC,
    batteryActualVoltage       Unsigned32,
    batteryActualCurrent       Integer32,
    batteryTemperature         Integer32,
    batteryCellIdentifier      SnmpAdminString,
    batteryAlarmLowCharge      Unsigned32,
    batteryAlarmLowVoltage     Unsigned32,
    batteryAlarmLowCapacity    Unsigned32,
    batteryAlarmHighCycleCount Unsigned32,
    batteryAlarmHighTemperature Integer32,
    batteryAlarmLowTemperature Integer32
}
```

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 re-installed 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 identifier cannot be represented using the ISO/IEC IS 10646-1 character set, then a hexadecimal encoding of a binary representation of the 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 which are not really batteries but often used in the same way as a battery.

The value other(2) can be used if the battery type is known but 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 types are registered at IANA. A current list of assignments can be found at <<http://www.iana.org/assignments/eman>>.

Value 0 (unknown) MUST be used if the type of battery cannot be determined.

Value 1 (other) can be used if the battery type is known but 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 maximal current to be used for charging the battery in units of milliampere (mA).

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

A value of 0 indicates that the maximal 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 current to be used for trickle charging the battery in units of milliampere (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 milliampere hours (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(1) 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),
 fastCharging(3),
 maintainingCharge(4),
 noCharging(5),
 discharging(6)
}

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 that the charge of the battery increases.

Value fastCharging(3) indicated that the battery is being charged rapidly, i.e. faster than in the charging(2) state. If multiple fast charging states exist, all of these states are indicated by fastCharging(3).

Value maintainingCharge(4) indicates that the battery is being charged with a low current that compensates

self-discharging. This includes trickle charging, float charging and other methods for maintaining the current charge of a battery.

Value noCharging(5) 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(6) indicates that the battery is being discharged and that the charge of the battery decreases."
 ::= { batteryEntry 13 }

batteryChargingAdminState OBJECT-TYPE

```
SYNTAX      INTEGER {
                charging(2),
                fastCharging(3),
                maintainingCharge(4),
                noCharging(5),
                discharging(6),
                notSet(7)
            }
```

MAX-ACCESS read-write

STATUS current

DESCRIPTION

"The value of this object indicates the desired status of the 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(7).

However, a SET request can only set this object to either charging(2), fastCharging(3), maintainingCharge(4), noCharging(5), or discharging(6). Attempts to set this object to notSet(7) will always fail with an 'inconsistentValue' error. In case multiple fast charging states exist, the battery logic can choose an appropriate fast charging state - preferably the fastest.

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.

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. For example, setting batteryChargingAdminState to value fastCharging(3) may have no effect when the battery logic is not allowing fast charging due to temperature constraints."

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

batteryActualCharge OBJECT-TYPE

```
SYNTAX      Unsigned64TC
UNITS       "milliampere hours"
MAX-ACCESS  read-only
STATUS      current
DESCRIPTION
```

"This object provides the actual charge of the battery in units of milliampere hours (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 millivolt (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 milliampere (mA). Charging current is represented by positive values, 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 near the battery.

 A value of '7fffffff'H indicates that the temperature cannot be determined."
 ::= { batteryEntry 18 }

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, for example, lithium polymer batteries for which battery controllers monitor cells individually.

 This object is used by notifications of type 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 details by specifying a single cell or a set of cells within the battery which are 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 just indicates the battery for which the temperature is exceeded but also the particular cell.

The initial value of this object is the empty string. The value of this object is set at each time a batteryLowNotification, a batteryTemperatureNotification, a batteryCriticalNotification, or a 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 19 }

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) enter a 'sleep' or 'off' state.

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

::= { batteryEntry 20 }

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) enter a 'sleep' or 'off' state.

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

::= { batteryEntry 21 }

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 22 }

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 23 }

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 24 }

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 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.

The notification should not be sent again before the current voltage or the current charge becomes higher than the respective thresholds through charging before falling below the thresholds again.

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."

```
::= { 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 powered device(s) or for a transition into an 'off' mode.

The notification should not be sent again before the battery charge has increased to a non-critical value.

If the critical state is caused 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."

::= { 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."

::= { 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."

::= { 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 compliance with this compliance statement requires compliance with the entity4CRCCompliance MODULE-COMPLIANCE statement of the ENTITY-MIB (RFC6933)."

```
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 to this object."

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

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

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

```
OBJECT batteryTemperatureNotification
MIN-ACCESS read-only
DESCRIPTION
    "A compliant implementation is not required
    to support set operations to 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 can have a negative effect on network operations. 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 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 either lead to a costly replacement of a working battery or too old or too weak batteries being used. The consequence of the latter could e.g. be that 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 modify the alarm behavior by setting them to any other value. The result may e.g. be an unnecessary shutdown of a device if batteryAlarmHighTemperature is set to too low or damage to the device by too high temperatures if switched off or set to too high values or by damage to the battery when it e.g. is being charged. Batteries can also be damaged e.g. in an attempt to charge them at too low temperatures.

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, privacy issues need to be considered. It may be a trade secret of the operator

- o how many batteries are installed in a managed node (batteryIndex)
- o how old these batteries are (batteryActualCapacity and batteryChargingCycleCount)
- o when the next replacement cycle for batteries can be expected (batteryAlarmLowCapacity and batteryAlarmHighCycleCount)
- o what battery type and make are used with which firmware version (batteryIdentifier, batteryFirmwareVersion, batteryType, and batteryTechnology)

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.

It is RECOMMENDED that implementers consider the security features as provided by the SNMPv3 framework (see [RFC3410], section 8), including full support for the SNMPv3 cryptographic mechanisms (for authentication and privacy).

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 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 xxx }

[NOTE for IANA: Please allocate an object identifier at <http://www.iana.org/assignments/smi-numbers> for object batteryMIB.]

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/eman> 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.

[NOTE for IANA: Please create a new registry under <http://www.iana.org/assignments/eman> for battery types. Please fill the registry with values from the table in Section 3.2]

7. Acknowledgements

We would like to thank Steven Chew and Bill Mielke for their valuable input.

8. References

8.1. Normative References

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