OpenDCRE Documentation

Release 1.3.0

Vapor IO

February 24, 2017

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CHAPTER 1

OpenDCRE

Introduction

OpenDCRE provides a securable RESTful API for monitoring and out-of-band management of data center and IT equipment. It can be configured to use power line communications (PLC) over a DC bus bar, IPMI over LAN, or Redfish over LAN. The OpenDCRE API is easy to integrate into third-party monitoring, management, and orchestration providers while providing a simple `curl`-able interface for common and custom devops tasks.

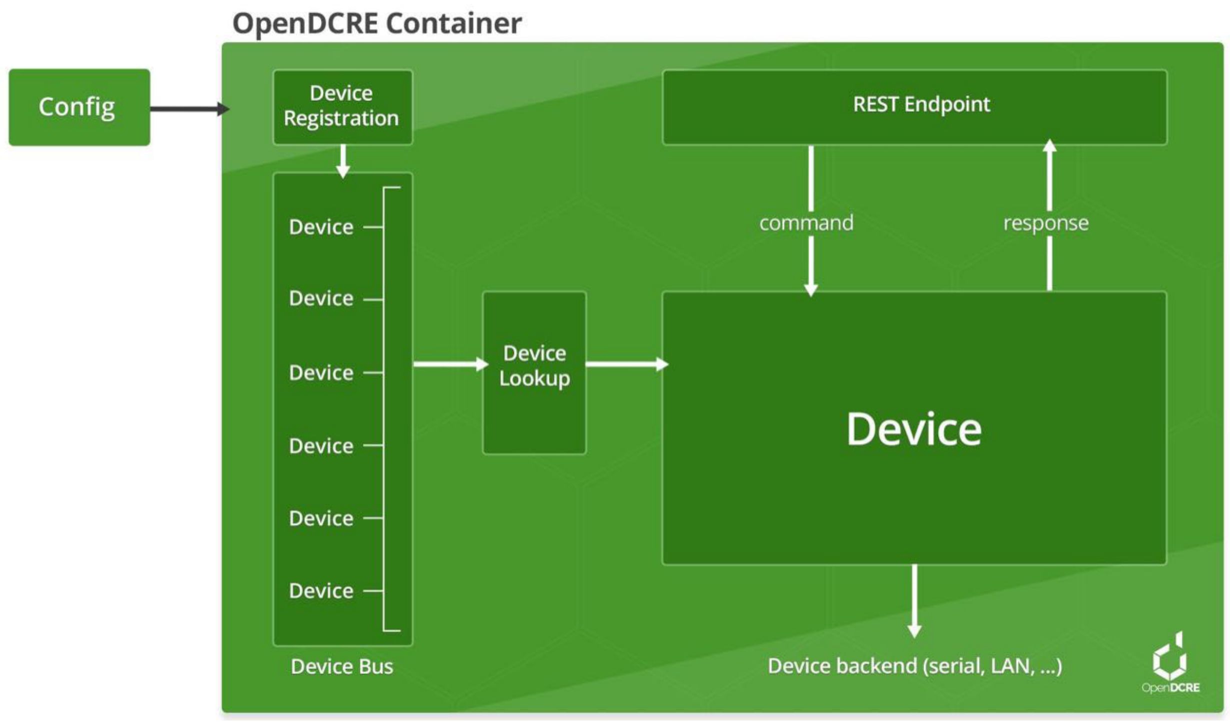
Note: Redfish support in OpenDCRE (v1.3.0) is still under development and testing, so it should be treated as a beta feature.

Features

- Simple `curl`-able RESTful API
- Analog and digital sensor support (temperature, thermistor, humidity, fan speed, pressure).
- Power control and status, including power consumption and power supply status.
- Asset information for servers.
- Physical and chassis location awareness.
- Fan speed control and status.
- Chassis "identify" LED control and status.
- System boot target selection (hdd, pxe).
- Securable via TLS/SSL.
- Integration with existing Auth providers (OAuth, LDAP, AD, etc.).
- Power line communications (PLC) - all OpenDCRE commands can use PLC over a DC bus bar as transport layer.
- IPMI Bridge - all OpenDCRE commands can use IPMI 2.0 over LAN as transport layer.
- Redfish support (beta) - all OpenDCRE commands can use Redfish over LAN as transport layer.

Architecture

OpenDCRE is a Dockerized service designed to run in a microservice architecture. It exposes a RESTful API via an HTTP endpoint in the OpenDCRE container. The HTTP endpoint is comprised of Nginx as the front-end with uwsgi as a reverse proxy for a Python Flask application. Within the Flask application, OpenDCRE a modular "device bus" definitions to define their own protocol-specific backends. The OpenDCRE endpoint routes and dispatches incoming commands to the appropriate device bus for handling.



The OpenDCRE device bus is comprised of a set of boards and devices, individually addressable, and globally scannable for a real-time inventory of addressable devices. The OpenDCRE device bus allows devices to be read and written, and for various actions to be carried out, such as power control (on/off/cycle/status). Additionally, when a physical OpenDCRE device bus is not present, a software emulator can be used to simulate OpenDCRE API commands and functionality.

All included components of OpenDCRE can be customized, integrated and secured via configuration file (nginx, uwsgi), and output their logs to a common location (/logs).

Applications

OpenDCRE can be used as an open platform for monitoring and managing data center hardware, software and environmental characteristics. Since OpenDCRE is Dockerized, there are a wide variety of options for deployments, integrations, network connectivity, etc. Community support helps OpenDCRE grow, and enables new functionality.

Requirements

- **Docker (preferably version 1.12 or later)**
  - used to containerize OpenDCRE, LAN based emulators, and tests.
- **docker compose (preferably version 1.10 or later)**

  - used for orchestrating and running OpenDCRE tests.
  - can be used to run OpenDCRE and LAN based emulators.
- **make**
  - used as the primary means for building and running OpenDCRE, emulator, and test images.

API Reference

The examples below assume OpenDCRE is running on a given <*ipaddress*> and <*port*>. The default port for OpenDCRE is TCP port 5000. Currently, all commands are GET requests; a future version will expose these commands via POST as well.

Note: In the API reference information below, there are many references to `board_id` and `device_id` parameters. For IPMI Devices, the values in a board's `hostnames` and `ip_addresses` fields (e.g. from a *scan*) can be used in place of the `board_id`. Additionally, the `device_info` field for a given device, where specified, can be used in place of its `device_id`.

As an example, a device *read* for a system temperature device on a board whose (abridged) scan information provides us with:

```
{
  "board_id": "40000039",
  "devices": [
    {
      "device_id": "0011",
      "device_info": "System Temp",
      "device_type": "temperature"
    }
  ],
  "hostnames": [
    "kafka001.vapor.io"
  ],
  "ip_addresses": [
    "192.168.1.10"
  ]
}
```

We could formulate a temperature read call in a variety of ways:

```
GET /opendcre/1.3/read/temperature/rack_9/40000039/0011
GET /opendcre/1.3/read/temperature/rack_9/40000039/System%20Temp
GET /opendcre/1.3/read/temperature/rack_9/kafka001.vapor.io/0011
GET /opendcre/1.3/read/temperature/rack_9/kafka001.vapor.io/System%20Temp
GET /opendcre/1.3/read/temperature/rack_9/192.168.1.10/0011
GET /opendcre/1.3/read/temperature/rack_9/192.168.1.10/System%20Temp
```

As of version 1.3.0, this only works for IPMI Devices, but this functionality will come later for all other devices.

asset information

Get asset information for a given device. The device's `device_type` must be of type `system` (as reported by the *scan* command). Asset information can consist of board information, chassis information, and product information.

Request

Format

```
GET /opendcre/<version>/asset/<rack_id>/<board_id>/<device_id>
```

Parameters

rack_id The id of the rack on which the specified board and device reside.

board_id Hexadecimal string representation of 4-byte integer value - range 00000000..FFFFFFFF. Upper byte of `board_id` reserved for future use in OpenDCRE. IPMI Bridge board has a special `board_id` of 40NNNNNN, where NNNNNN corresponds to the hex string id of each configured BMC. For IPMI, the `board_id` can also be a hostname/ip_address that is associated with the given board.

device_id The device to read asset information for on the specified board. Hexadecimal string representation of a 2-byte integer value - range 0000..FFFF. Must be a valid, existing device, where the `device_type` known to OpenDCRE is of type `system` - else, a 500 error is returned. For IPMI, the `device_id` can also be the value of the `device_info` field associated with the given device, if present.

Example

```
http://opendcre:5000/opendcre/1.3/asset/00000001/0004
```

Response

Schema

```
{
  "$schema": "http://schemas.vapor.io/opendcre/v1.3/opendcre-1.3-asset-information",
  "title": "OpenDCRE Asset Information",
  "type": "object",
  "properties": {
    "bmc_ip": {
      "type": "string"
    },
    "board_info": {
      "type": "object",
      "properties": {
        "manufacturer": {
          "type": "string"
        },
        "part_number": {
          "type": "string"
        },
        "product_name": {
          "type": "string"
        },
        "serial_number": {
          "type": "string"
        }
      }
    },
    "chassis_info": {
      "type": "object",
      "properties": {
        "chassis_type": {
          "type": "string"
        },
        "part_number": {
          "type": "string"
        },
        "serial_number": {
          "type": "string"
        }
      }
    },
    "product_info": {
      "type": "object",
      "properties": {
        "asset_tag": {
          "type": "string"
        },
        "manufacturer": {
          "type": "string"
        },
        "part_number": {
          "type": "string"
        },
        "product_name": {
          "type": "string"
        },
        "serial_number": {
          "type": "string"
        },
        "version": {
          "type": "string"
        }
      }
    }
  }
}
}
```

Note: Note that the `bmc_ip` field is only present for IPMI device asset info.

Example

```
{
  "bmc_ip": "192.168.1.118",
  "board_info": {
    "manufacturer": "Quanta",
    "part_number": "0001",
    "product_name": "Winterfell",
    "serial_number": "S1234567"
  },
  "chassis_info": {
    "chassis_type": "rack mount chassis",
    "part_number": "P1234567",
    "serial_number": "S1234567"
  },
  "product_info": {
    "asset_tag": "A1234567",
    "manufacturer": "Quanta",
    "part_number": "P1234567",
    "product_name": "Winterfell",
    "serial_number": "S1234567",
    "version": "v1.2.0"
  }
}
```

Errors

500

- asset info is unavailable or does not exist
- specified device is not of type `system`
- invalid/nonexistent `board_id` or `device_id`

---

boot target

The boot target command may be used to get or set the boot target for a given device (whose device_type must be `system`). The boot_target command takes two required parameters - `board_id` and `device_id`, to identify the device to direct the boot_target command to. Additionally, a third, optional parameter, `target` may be used to set the boot target.

Request

Format

```
GET /opendcre/<version>/boot_target/<rack_id>/<board_id>/<device_id>[/<target>]
```

Parameters

rack_id The id of the rack upon which the specified board and device reside.

board_id Hexadecimal string representation of 4-byte integer value - range 00000000..FFFFFFFF. Upper byte of `board_id` reserved for future use in OpenDCRE. IPMI Bridge board has a special `board_id` of 40NNNNNN, where NNNNNN corresponds to the hex string id of each configured BMC. For IPMI, the `board_id` can also be a hostname/ip_address that is associated with the given board.

device_id The device to issue boot target command to on the specified board. Hexadecimal string representation of 2-byte integer value - range 0000..FFFF. Must be a valid, existing device, where the `device_type` known to OpenDCRE is `system` - else, a 500 error is returned. For IPMI, the `device_id` can also be the value of the `device_info` field associated with the given device, if present.

target *(optional)* Valid target for the boot_target command include:

- `hdd` : boot to hard disk
- `pxe` : boot to network
- `no_override` : use the system default boot target

If a target is not specified, boot_target makes no changes, and simply retrieves and returns the system boot target. If `target` is specified and valid, the boot_target command will return the updated boot target value, as provided by the remote device.

Example

```
http://opendcre:5000/opendcre/1.3/boot_target/00000001/0004
```

Response

Schema

```
{
  "$schema": "http://schemas.vapor.io/opendcre/v1.3/opendcre-1.3-boot-target",
  "title": "OpenDCRE Boot Target",
  "type": "object",
  "properties": {
    "target": {
      "type": "string",
      "enum": [
        "no_override",
        "hdd",
        "pxe"
      ]
    }
  }
}
```

Example

```
{
  "target": "no_override"
}
```

Errors

500

- boot target action fails
- specified device is not of type `system`
- invalid/nonexistent `board_id` or `device_id`

fan

The fan control command is used to get the fan speed (in RPM) for a given fan.

Request

Format

```
GET /opendcre/<version>/fan/<rack_id>/<board_id>/<device_id>[/<speed_rpm>]
```

Parameters

rack_id The id of the rack upon which the specified board and device reside.

board_id Hexadecimal string representation of 4-byte integer value - range 00000000..FFFFFFFF. Upper byte of `board_id` reserved for future use in OpenDCRE. IPMI Bridge board has a special `board_id` of 40NNNNNN, where NNNNNN corresponds to the hex string id of each configured BMC. For IPMI, the `board_id` can also be a hostname/ip_address that is associated with the given board.

device_id The device to issue fan control command to on the specified board. Hexadecimal string representation of 2-byte integer value - range 0000..FFFF. Must be a valid, existing device, where the `device_type` known to OpenDCRE is `fan_speed` - else, a 500 error is returned. For IPMI, the `device_id` can also be the value of the `device_info` field associated with the given device, if present.

speed_rpm *(optional)* Numeric decimal value to set fan speed to, in range of 0-10000.

Note: IPMI devices do not yet support the setting of fan speed, so this parameter can be ignored for all IPMI setups.

Example

```
http://opendcre:5000/opendcre/1.3/fan/00000001/0002
```

Response

Schema

```
{
  "$schema": "http://schemas.vapor.io/opendcre/v1.3/opendcre-1.3-fan-speed",
  "title": "OpenDCRE Fan Speed",
  "type": "object",
  "properties": {
    "health": {
      "type": "string"
    },
    "states": {
      "type": "array"
    },
    "speed_rpm": {
      "type": "number"
    }
  }
}
```

Example

```
{
  "health": "ok",
  "speed_rpm": 4100.0,
  "states": []
}
```

Errors

500

- fan speed action fails
- specified device is not a fan device
- invalid/nonexistent `board_id` or `device_id`

host information

Get the hostname(s) and IP address(es) for a given host. The device's `device_type` should be of type `system` (as reported by the *scan* command).

Request

Format

```
GET /opendcre/<version>/host_info/<rack_id>/<board_id>/<device_id>
```

Parameters

rack_id The id of the rack upon which the specified board and device reside.

board_id Hexadecimal string representation of 4-byte integer value - range 00000000..FFFFFFFF. Upper byte of `board_id` reserved for future use in OpenDCRE. IPMI Bridge board has a special `board_id` of 40NNNNNN, where NNNNNN corresponds to the hex string id of each configured BMC. For IPMI, the `board_id` can also be a hostname/ip_address that is associated with the given board.

device_id The device to issue host info control command to on the specified board. Hexadecimal string representation of 2-byte integer value - range 0000..FFFF. Must be a valid, existing device, where the `device_type` known to OpenDCRE is `system` - else, a 500 error is returned. For IPMI, the `device_id` can also be the value of the `device_info` field associated with the given device, if present.

Example

```
http://opendcre:5000/opendcre/1.3/host_info/00000001/0001
```

Response

Schema

```
{
  "$schema": "http://schemas.vapor.io/opendcre/v1.3/opendcre-1.3-host-information",
  "title": "OpenDCRE Host Information",
  "type": "object",
  "properties": {
    "hostnames": {
      "type": "array",
      "items": {
        "type": "string"
      }
    },
    "ip_addresses": {
      "type": "array",
      "items": {
        "type": "string"
      }
    }
  }
}
```

Example

```
{
  "hostnames": [
    "cassandra000"
  ],
  "ip_addresses": [
    "10.10.1.16"
  ]
}
```

Errors

500

- host info action fails
- specified device is not of type `system`

- invalid/nonexistent `board_id` or `device_id`

LED

The LED control command is used to get and set the chassis "identify" LED state. `led` devices known to OpenDCRE allow LED state to be set and retrieved.

Request

Format

```
GET /opendcre/<version>/led/<rack_id>/<board_id>/<device_id>[/<led_state>]
```

Parameters

rack_id The id of the rack upon which the specified board and device reside.

board_id Hexadecimal string representation of 4-byte integer value - range 00000000..FFFFFFFF. Upper byte of `board_id` reserved for future use in OpenDCRE. IPMI Bridge board has a special `board_id` of 40NNNNNN, where NNNNNN corresponds to the hex string id of each configured BMC. For IPMI, the `board_id` can also be a hostname/ip_address that is associated with the given board.

device_id The device to issue LED control command to on the specified board. Hexadecimal string representation of 2-byte integer value - range 0000..FFFF. Must be a valid, existing device, where the `device_type` known to OpenDCRE is `led` - else, a 500 error is returned. For IPMI, the `device_id` can also be the value of the `device_info` field associated with the given device, if present.

led_state *(optional)* The LED state to set. Valid values include:

- `on` : Turn on the chassis identify LED
- `off` : Turn off the chassis identify LED

Example

```
http://opendcre:5000/opendcre/1.3/led/00000001/0005
```

Response

Schema

```
{
  "$schema": "http://schemas.vapor.io/opendcre/v1.3/opendcre-1.3-led-control",
  "title": "OpenDCRE LED Control",
  "type": "object",
  "properties": {
    "led_state": {
      "type": "string",
      "enum": [
        "on",
        "off"
      ]
    }
  }
}
```

Example

```
{
  "led_state": "on"
}
```

Errors

500

- LED control action fails
- specified device is not of type `led`
- invalid `board_id` or `device_id`

---

location

The location command returns the physical location of a given board in the rack, if known, and may also include a given device's position within a chassis (when the `device_id` parameter is specified). IPMI boards return `unknown` for all fields of `physical_location` as location information is not provided by IPMI.

Request

Format

```
GET /opendcre/<version>/location/<rack_id>/<board_id>[/<device_id>]
```

Parameters

rack_id The id of the rack upon which the specified board and device reside.

board_id Hexadecimal string representation of 4-byte integer value - range 00000000..FFFFFFFF. Upper byte of `board_id` reserved for future use in OpenDCRE. IPMI Bridge board has a special `board_id` of 40NNNNNN, where NNNNNN corresponds to the hex string id of each configured BMC. For IPMI, the `board_id` can also be a hostname/ip_address that is associated with the given board.

device_id *(optional)* The device to get location for on the specified board. Hexadecimal string representation of 2-byte integer value - range 0000..FFFF. Must be a valid, existing device known to OpenDCRE - else, a 500 error is returned. For IPMI, the `device_id` can also be the value of the `device_info` field associated with the given device, if present.

Response

Schema

Device Location

```
{
  "$schema": "http://schemas.vapor.io/opendcre/v1.3/opendcre-1.3-device-location",
  "title": "OpenDCRE Device Location",
  "type": "object",
  "properties": {
    "chassis_location": {
      "type": "object",
      "properties": {
        "depth": {
          "type": "string",
          "enum": [
            "unknown",
            "front",
            "middle",
            "rear"
          ]
        },
        "horiz_pos": {
          "type": "string",
          "enum": [
            "unknown",
            "left",
            "middle",
            "right"
          ]
        },
        "vert_pos": {
          "type": "string",
          "enum": [
            "unknown",
            "top",
            "middle",
            "bottom"
          ]
        },
        "server_node": {
          "type": "string"
        }
      }
    },
    "physical_location": {
      "type": "object",
      "properties": {
        "depth": {
          "type": "string",
          "enum": [
            "unknown",
            "front",
            "middle",
            "rear"
          ]
        },
        "horizontal": {
          "type": "string",
          "enum": [
            "unknown",
            "left",
            "middle",
            "right"
          ]
        },
        "vertical": {
          "type": "string",
          "enum": [
            "unknown",
            "top",
            "middle",
            "bottom"
          ]
        }
      }
    }
  }
}
```

Board Location

```
    {
      "$schema": "http://schemas.vapor.io/opendcre/v1.3/opendcre-1.3-board-location",
      "title": "OpenDCRE BoardLocation",
      "type": "object",
      "properties": {
        "physical_location": {
          "type": "object",
          "properties": {
            "depth": {
              "type": "string",
              "enum": [
                "unknown",
                "front",
                "middle",
                "rear"
              ]
            },
            "horizontal": {
              "type": "string",
              "enum": [
                "unknown",
                "left",
                "middle",
                "right"
              ]
            },
            "vertical": {
              "type": "string",
              "enum": [
                "unknown",
                "top",
                "middle",
                "bottom"
              ]
            }
          }
        }
      }
    }
```

Example

Device Location

```
      {
        "chassis_location": {
          "depth": "unknown",
          "horiz_pos": "unknown",
          "server_node": "unknown",
          "vert_pos": "unknown"
        },
        "physical_location": {
          "depth": "unknown",
          "horizontal": "unknown",
          "vertical": "unknown"
        }
      }
```

Board Location

```
      {
        "physical_location": {
          "depth": "unknown",
          "horizontal": "unknown",
          "vertical": "unknown"
        }
      }
```

Errors

500

- location command fails
- invalid/nonexistent `board_id` or `device_id`

power

Control device power, and/or retrieve its power supply status. The specified device's `device_type` must be of type `power` (as reported by the *scan* command).

Request

Format

```
GET /opendcre/<version>/power/<rack_id>/<board_id>/<device_id>[/<command>]
```

Parameters

rack_id The id of the rack which the specified board and device reside on.

board_id Hexadecimal string representation of 4-byte integer value - range 00000000..FFFFFFFF. Upper byte of `board_id` reserved for future use in OpenDCRE. IPMI Bridge board has a special `board_id` of 40NNNNNN, where NNNNNN corresponds to the hex string id of each configured BMC. For IPMI, the `board_id` can also be a hostname/ip_address that is associated with the given board.

device_id The device to issue power command to on the specified board. Hexadecimal string representation of 2-byte integer value - range 0000..FFFF. Must be a valid, existing device, where the `device_type` known to OpenDCRE is `power` - else, a 500 error is returned. For IPMI, the `device_id` can also be the value of the `device_info` field associated with the given device, if present.

command *(optional)* The power command to issue. Valid commands are:

- `on` : Turn power on to specified device
- `off` : Turn power off to specified device
- `cycle` : Power-cycle the specified device
- `status` : Get power status for the specified device

For all commands, power status is returned as the command's response.

Example

```
http://opendcre:5000/opendcre/1.3/power/00000001/000d/on
```

Response

Schema

```
{
  "$schema": "http://schemas.vapor.io/opendcre/v1.3/opendcre-1.3-power-status",
  "title": "OpenDCRE Power Status",
  "type": "object",
  "properties": {
    "input_power": {
      "type": "number"
    },
    "input_voltage": {
      "type": "number"
    },
    "output_current": {
      "type": "number"
    },
    "over_current": {
      "type": "boolean"
    },
    "pmbus_raw": {
      "type": "string"
    },
    "power_ok": {
      "type": "boolean"
    },
    "power_status": {
      "type": "string",
      "enum": [
        "on",
        "off"
      ]
    },
    "under_voltage": {
      "type": "boolean"
    }
  }
}
```

Example

```
{
  "input_power": 198.57686579513486,
  "input_voltage": 12.500651075576853,
  "output_current": 15.879801734820322,
  "over_current": false,
  "pmbus_raw": "0,12000,2400,3356",
  "power_ok": true,
  "power_status": "on",
  "under_voltage": false
}
```

Errors

500

- power action fails
- the specified device is not of type `power`
- invalid/nonexistent `board_id` or `device_id`

read

Read a value from the given `board_id` and `device_id` for a specific `device_type`. The specified `device_type` must match the actual physical device type (as reported by the *scan* command), and is used to return a translated raw reading value (e.g. temperature in C for a thermistor) based on the existing algorithm for a given sensor type.

Request

Format

```
GET /opendcre/<version>/read/<device_type>/<rack_id>/<board_id>/<device_id>
```

Parameters

device_type String value (lower-case) indicating what type of device to read: `thermistor`, `temperature`, `humidity`, `led`, `fan_speed`, `pressure`, `voltage`

rack_id The id of the rack which the board and device reside on.

board_id Hexadecimal string representation of 4-byte integer value - range 00000000..FFFFFFFF. Upper byte of `board_id` reserved for future use in OpenDCRE. IPMI Bridge board has a special `board_id` of 40NNNNNN (where NNNNNN is the hex string id of each individual BMC configured with the IPMI Bridge). For IPMI, the `board_id` can also be a hostname/ip_address that is associated with the given board.

device_id The device to read on the specified board. Hexadecimal string representation of a 2-byte integer value - range 0000..FFFF. Must be a valid, existing device, where the `device_type` known to OpenDCRE matches the `device_type` specified in the command for the given device - else, a 500 error is returned. For IPMI, the `device_id` can also be the value of the `device_info` field associated with the given device, if present.

Example

```
http://opendcre:5000/opendcre/1.3/read/thermistor/00000001/0001
```

Response

Schema

```
{
  "$schema": "http://schemas.vapor.io/opendcre/v1.3/opendcre-1.3-sensor-reading",
  "title": "OpenDCRE Sensor Reading",
  "type": "object",
  "oneOf": [
    {
      "description": "Temperature Readings",
      "properties": {
        "health": {
          "type": "string"
        },
        "states": {
          "type": "array"
        },
        "temperature_c": {
          "type": "number"
        }
      }
    },
    {
      "description": "Thermistor Readings",
      "properties": {
        "health": {
          "type": "string"
        },
        "states": {
          "type": "array"
        },
        "temperature_c": {
          "type": "number"
        }
      }
    },
    {
      "description": "Fan Speed Readings",
      "properties": {
        "health": {
          "type": "string"
        },
        "states": {
          "type": "array"
        },
        "speed_rpm": {
          "type": "number"
        }
      }
    },
    {
      "description": "LED Readings",
      "properties": {
        "health": {
          "type": "string"
        },
        "states": {
          "type": "array"
        },
        "led_state": {
          "type": "string",
          "enum": [
            "on",
            "off"
          ]
        }
      }
    },
    {
      "description": "Pressure Readings",
      "properties": {
        "health": {
          "type": "string"
        },
        "states": {
          "type": "array"
        },
        "pressure_kpa": {
          "type": "number"
        }
      }
    },
    {
      "description": "Voltage Readings",
      "properties": {
        "health": {
          "type": "string"
        },
        "states": {
          "type": "array"
        },
        "voltage": {
          "type": "number"
        }
      }
    }
  ]
}
```

Example

```
{
  "health": "ok",
  "states": [],
  "temperature_c": 19.73
}
```

Errors

500

- the device is not readable or does not exist
- specified device is not of the specified device type
- invalid/nonexistent `board_id` or `device_id`

scan

The `scan` command polls boards and devices attached to the board. There are primarily two ways that scan operates – “scan all”, and “scan entity”, where an entity could be a rack or a board. When performing a “scan all” command, if a scan cache does not exist, it will scan the physical boards and devices. If a scan cache does exist, it will use the results from the cache. To refresh the scan cache, the “force scan” command should be used.

Note: It is likely a good idea for applications to scan for all boards on startup, to ensure a proper map of boards and devices is available to the application. Mismatches of board and device types and identifiers will result in 500 errors being returned for various commands that rely on these values mapping to actual hardware.

Request

Format

scan all

```
GET /opendcre/<version>/scan
```

force scan

```
GET /opendcre/<version>/scan/force
```

scan rack

```
GET /opendcre/<version>/<rack_id>
```

scan board

```
GET /opendcre/<version>/<rack_id></board_id>
```

Parameters

force *(optional)* A flag which, when present, will force the re-scan of all racks, boards, and devices. This parameter is only associated with "scan all" behavior and does not apply to scans at a rack or board level. Forcing a scan re-scans the devices and updates the scan cache.

rack_id *(optional)* The id of the rack to scan, if only the rack is specified. If the rack is specified with a board id, this is the rack where the target board resides.

board_id *(optional)* Hexadecimal string representation of 4-byte integer value - range 00000000..FFFFFFFF. Upper byte of `board_id` reserved for future use in OpenDCRE. IPMI Bridge boards have a special `board_id` of 40NNNNNN (where NNNNNN is the hex string id of each configured BMC). For IPMI, the `board_id` can also be a hostname/ip_address that is associated with the given board.

Example

```
GET http://opendcre:5000/opendcre/1.3/scan
GET http://opendcre:5000/opendcre/1.3/scan/force
GET http://opendcre:5000/opendcre/1.3/scan/rack_1
GET http://opendcre:5000/opendcre/1.3/scan/rack_1/00000001
```

Response

Schema

```
{
  "$schema": "http://schemas.vapor.io/opendcre/v1.3/opendcre-1.3-boards-devices",
  "title": "OpenDCRE Boards and Devices",
  "type": "object",
  "properties": {
    "racks": {
      "type": "array",
      "items": {
        "type": "object",
        "properties": {
          "rack_id": {
            "type": "string"
          },
          "boards": {
            "type": "array",
            "items": {
              "type": "object",
              "properties": {
                "board_id": {
                  "type": "string"
                },
                "devices": {
                  "type": "array",
                  "items": {
                    "type": "object",
                    "properties": {
                      "device_id": {
                        "type": "string"
                      },
                      "device_type": {
                        "type": "string",
                        "enum": [
                          "temperature",
                          "thermistor",
                          "humidity",
                          "led",
                          "system",
                          "power",
                          "fan_speed",
                          "pressure",
                          "voltage",
                          "power_supply"
                        ]
                      }
                    }
                  }
                },
                "hostnames": {
                  "type": "array",
                  "items": {
                    "type": "string"
                  }
                },
                "ip_addresses": {
                  "type": "array",
                  "items": {
                    "type": "string"
                  }
                },
              }
            }
          }
        }
      }
    }
  }
}
```

Example

```
{
  "racks": [
    {
      "boards": [
        {
          "board_id": "00000001",
          "devices": [
            {
              "device_id": "0001",
              "device_type": "system"
            },
            {
              "device_id": "0002",
              "device_type": "fan_speed"
            },
            {
              "device_id": "0003",
              "device_type": "fan_speed"
            },
            {
              "device_id": "0004",
              "device_type": "power"
            },
            {
              "device_id": "0005",
              "device_type": "led"
            },
            {
              "device_id": "2000",
              "device_type": "temperature"
            },
            {
              "device_id": "4000",
              "device_type": "temperature"
            }
          ],
          "hostnames": [
            "kafka001.vapor.io"
          ],
          "ip_addresses": [
            "192.168.1.10"
          ]
        }
      ],
      "rack_id": "rack_1"
    }
  ]
}
```

Errors

500

- the scan command fails
- invalid/nonexistent `board_id`

---

service version

The OpenDCRE service version command identifies the version of OpenDCRE running on the OpenDCRE instance being queried. Since OpenDCRE's REST API commands include the API version in the URI, this endpoint provides a means of getting that version if it is otherwise unknown.

Request

Format

```
GET /opendcre/version
```

Response

Schema

```
{
  "$schema": "http://schemas.vapor.io/opendcre/v1.3/opendcre-1.3-service-version",
  "title": "OpenDCRE Service Version",
  "type": "object",
  "properties": {
    "version": {
      "type": "string"
    }
  }
}
```

Example

```
{
  "version": "1.3"
}
```

Errors

500

- the endpoint is not running

---

test

The test command provides a way to verify that the OpenDCRE service is running. It has no dependencies on any of the configured devicebus interfaces, so it serves only to test that the service is up and reachable - not that it is configured correctly. The command takes no arguments and, if successful, returns a status message of "ok".

Request

Format

```
GET  /opendcre/<version>/test
POST /opendcre/<version>/test
```

Response

Schema

```
{
  "$schema": "http://schemas.vapor.io/opendcre/v1.3/opendcre-1.3-test-status",
  "title": "OpenDCRE Test Status",
  "type": "object",
  "properties": {
    "status": {
      "type": "string"
    }
  }
}
```

Example

```
{
  "status": "ok"
}
```

Errors

500

- the endpoint is not running

---

version

Get version information about a board.

Request

Format

```
GET /opendcre/<version>/version/<rack_id>/<board_id>
```

Parameters

rack_id The rack id associated with the specified board.

board_id Hexadecimal string representation of 4-byte integer value - range 00000000..FFFFFFFF. Upper byte of `board_id` reserved for future use in OpenDCRE. IPMI Bridge board has a special `board_id` of 40000000. For IPMI, the `board_id` can also be a hostname/ip_address that is associated with the given board.

Example

```
http://opendcre:5000/opendcre/1.3/version/00000001
```

Response

Schema

```
{
  "$schema": "http://schemas.vapor.io/opendcre/v1.3/opendcre-1.3-version",
  "title": "OpenDCRE Board Version",
  "type": "object",
  "properties": {
    "api_version": {
      "type": "string"
    },
    "firmware_version": {
      "type": "string"
    },
    "opendcre_version": {
      "type": "string"
    }
  }
}
```

Example

```
{
  "api_version": "1.3",
  "firmware_version": "OpenDCRE Emulator v1.3.0",
  "opendcre_version": "1.3.0"
}
```

Errors

500

- version retrieval does not work
- `board_id` specifies a nonexistent board

Getting OpenDCRE

OpenDCRE's source can be found on GitHub, where the OpenDCRE Docker image will need to be built. Alternatively, a pre-built OpenDCRE image can be downloaded from DockerHub.

Building from Source

Once the OpenDCRE source code is downloaded (either via git clone, or downloaded zip), a Docker image can be built. No additional changes are required to the source for a complete, functioning image, but customizations can be included in the image, e.g. the inclusion of site-specific TLS certificates, nginx configurations for authn/authz, etc.

The included dockerfile can be used to package up the distribution:

```
docker build -t opendcre:custom-v1.3.0 -f dockerfile/Dockerfile.x64 .
```

A Makefile recipe also exists to build the OpenDCRE image and tag it as `vaporio/opendcre-<arch>:1.3`, where *<arch>* specifies the architecture (e.g., x64). For the *x64* architecture, this recipe is:

```
make x64
```

If building a custom image, apply whatever tag is most descriptive for that image.

At this point, OpenDCRE can be tested (see *Testing*) and run (see *Running OpenDCRE*) to ensure the build was successful.

Downloading from DockerHub

If no changes are needed to the source, the pre-packed version can be used. It can be downloaded from DockerHub simply with

```
docker pull vaporio/opendcre:1.3.0
```

Updating

Updating OpenDCRE is as simple as building a new image from source, or pulling a new image down from Docker-Hub.

Configuring OpenDCRE

OpenDCRE may be customized in a variety of ways, most commonly through the OpenDCRE configuration file, but also through supporting configurations (e.g. Nginx configurations).

Configuration Options

OpenDCRE configurations are made up of two files – default configurations, and override configurations. As the name suggests, the default configurations are what come pre-built into OpenDCRE and what OpenDCRE will fall back to if no override is specified. The default configurations can be found at `/opendcre/default/default.json` in the OpenDCRE container.

```
{
  "scan_cache_file": "/tmp/opendcre/cache.json",
  "cache_timeout": 600,
  "cache_threshold": 500,

  "devices": {
    "ipmi": {
      "from_config": "bmc_config.json"
    }
  }
}
```

The override configurations are user-specified at run time. These configurations can be mounted into the container as a volume at `/opendcre/override/config.json`. The configuration override file can be any JSON file with “config” in the filename. Of course, configurations do not need to be volume-mounted into the container, though it is convenient in various situations. In cases where it is easier to just replace the default configuration altogether, do so and rebuild the OpenDCRE docker image (see *Building from Source*).

As an example, if we wanted to override the *cache_timeout* configuration, we could mount in `config.json` which contains:

```
{
  "cache_timeout": 1000
}
```

In this case, the default values will be used for everything but *cache_timeout*.

Below are descriptions for each of the supported configuration file fields.

scan_cache_file The path and filename of the file used to cache OpenDCRE data, such as board records used by the “scan” command. The default value of “/tmp/opendcre/cache.json” typically is suitable and does not need to be changed.

cache_timeout The scan cache’s time-to-live, in seconds, after which cache records will be invalidated.

cache_threshold The maximum number of entries to store in the scan cache.

devices The devices parameter is used to describe the various bus types and devices available to OpenDCRE. It accepts keys of “plc” (*PLC Device*), “ipmi” (*IPMI Device*), and “redfish” (*Redfish Device*), though none are required. See the linked sections for each devicebus type for examples of the configuration for each.

Continuing with the example above, we can see how actual devices are configured within the referenced IPMI config file, `bmc_config.json`:

```
{
  "racks": [
    {
      "rack_id": "rack_1",
      "bmcs": [
        {
          "bmc_ip": "192.168.1.110",
          "username": "ADMIN",
          "password": "ADMIN"
        },
        {
          "bmc_ip": "192.168.1.111",
          "bmc_port": 622,
          "username": "ADMIN",
          "password": "ADMIN",
          "hostnames": ["atom"],
          "ip_addresses": ["192.169.1.111"]
        }
      ]
    }
  ]
}
```

Here, we are configuring two BMCs, both on a single rack – "rack_1". The first BMC is at IP 192.168.1.110 with username ADMIN and password ADMIN. No port is specified, so it uses the default port of 623. The second BMC is at IP 192.168.1.111 with username ADMIN and password ADMIN. It has a non-standard port specified which will be used to communicate with that BMC.

See the *IPMI Device* section for greater detail on these configuration options.

Port

By default, OpenDCRE listens on port 5000. To change the port OpenDCRE listens on, edit the `opendcre_nginx.conf` file, and the port exposed in the Dockerfile, then rebuild the OpenDCRE docker image (see *Building from Source*).

```
server {
    listen 5000;
    server_name localhost;
    charset utf-8;
    access_log /logs/opendcre.net_access.log;
    error_log /logs/opendcre.net_error.log;

    location / {
        add_header 'Access-Control-Allow-Origin' '*';
        uwsgi_pass unix://var/uwsgi/opendcre.sock;
        include /etc/nginx/uwsgi_params;
    }
}
```

TLS/SSL

TLS/SSL certificates may be added to OpenDCRE via Nginx configuration. Refer to the Nginx documentation for instructions on how to enable TLS.

Authentication

As OpenDCRE uses Nginx as its reverse proxy, authentication may be enabled via Nginx configuration – see the Nginx documentation for instructions on how to enable authentication.

Running OpenDCRE

OpenDCRE is easy to start up - it just requires that the container be run. In the simplest case, OpenDCRE can be started with

```
docker run -p 5000:5000 vaporio/opendcre
```

But this wont do very much, since it will have no devices configured to issue commands to. To get OpenDCRE working with real or even emulated hardware, there is a bit of configuration that needs to be done. Below, there is a "Quick Start" approach to getting start with using OpenDCRE. After, the "Detailed Start" covers a bit more detail all the ways in which OpenDCRE can be configured for running.

Quick Start

For the quick start, we will assume that we will be using an emulator, though the principles here should naturally and clearly extend to real hardware as well. For simplicity, This will use a single emulator (for IPMI), but nothing prevents you from configuring it with multiple emulators/devices as you see fit.

See the *Emulators* section for more complete documentation on how to configure and run the emulators.

For this example, lets say our IPMI emulator is running on 192.168.1.10, with username 'admin' and password 'admin'.

A configuration file should be created which specifies this emulator, which we will save locally as `bmc_config.json`:

```
{
  "racks": {
    "rack_id": "rack_1",
    "bmcs": [
      {
        "bmc_ip": "192.168.1.10",
        "username": "admin",
        "password": "admin"
      }
    ]
  }
}
```

Next, we just need to run OpenDCRE and mount in the IPMI configuration file to the appropriate location.

```
docker run -p 5000:5000 -v `pwd`/bmc_config.json:/opendcre/bmc_config.json vaporio/opendcre:1.3
```

This will start OpenDCRE and reach out to 192.168.1.10 to register the IPMI Device and scan that BMC. To use your own BMCs, you would simply provide the appropriate IP, username, and password for each BMC configured.

Volume Mount Locations

Above, we say "mount the configuration to the appropriate location", but what are the appropriate locations?

Devicebus Type	Container Configuration File
plc	/opendcre/plc_config.json
ipmi	/opendcre/bmc_config.json
redfish	/opendcre/redfish_config.json

Detailed Start

OpenDCRE devices are all set up by configuration. These configurations can either be built directly into the image (if building a custom OpenDCRE image) or mounted into the container, which is the preferred approach as it is more flexible.

When OpenDCRE starts, it reads in is configuration files to determine which devices are configured. By default, OpenDCRE points to empty configurations for PLC, IPMI, and Redfish

```
{
  "devices": {
    "plc": {
      "from_config": "plc_config.json"
    },
    "ipmi": {
      "from_config": "bmc_config.json"
    },
    "redfish": {
      "from_config": "redfish_config.json"
    }
  }
}
```

Where each of those files specifies a single rack with no devices on it, e.g. for IPMI

```
{
  "racks": [
    {
      "rack_id": "rack_1",
      "bmcs": []
    }
  ]
}
```

So, when OpenDCRE starts up with no additional configurations provided, no devices will be registered with it, so it really won't be able to perform any actions.

In the Quick Start example, we overwrite the existing "blank" IPMI BMC configuration file with one that has an actual configuration in it (via the volume mount). With that, OpenDCRE will see that there is a device specified, and will attempt to register it so that it can be used to issue commands to.

This same pattern applies to the other devicebus types, so if you want to configure OpenDCRE to work with a PLC device and a Redfish device, you need only create the appropriate configuration files for them and volume-mount them to the OpenDCRE container on startup.

It helps to familiarize yourself with the *Configuring OpenDCRE* section as well as the configurations for the *PLC Device*, *IPMI Device*, and *Redfish Device* to know what configurations are required.

Below is an example (dummy) OpenDCRE run command followed by an explanation of what each part does.

```
docker run -d \
    -p 5000:5000 \
    -e VAPOR_DEBUG=true \
    -v `pwd`/plc_config.json:/opendcre/plc_config.json \
    -v `pwd`/ipmi_config.json:/opendcre/bmc_config.json \
    -v `pwd`/config_override.json:/opendcre/override/config.json \
    vaporio/opendcre \
    ./start_opendcre.sh
```

`-d` the `-d` flag is used to run OpenDCRE in "detached" mode - this means Docker will not attach to the console, so OpenDCRE will run in the background.

`-p 5000:5000` this maps the host's port 5000 to the OpenDCRE container's port 5000 - with this, you can use the OpenDCRE REST API on port 5000 of the host.

`-e VAPOR_DEBUG=true` this sets the `VAPOR_DEBUG` envirnment variable to `true`, enabling debug logging. For more on this, see the *Debugging* section.

`-v `pwd`/plc_config.json:/opendcre/plc_config.json` this mounts in the "plc_config.json" file from the host to the "/opendcre/plc_config.json" location in the container. this will override the default (empty) PLC configurations.

`-v `pwd`/ipmi_config.json:/opendcre/bmc_config.json` this mounts in the "ipmi_config.json" file from the host to the "/opendcre/bmc_config.json" location in the container. this will override the default (empty) IPMI configurations.

`-v `pwd`/config_override.json:/opendcre/override/config.json` this mounts in the "config_override.json" file from the host to the "/opendcre/override/config.json" location in the container. this is used to override defaualt OpenDCRE configurations (including but not limited to device configurations). See the *Configuring OpenDCRE* section for more on this.

`vaporio/opendcre` this is the image to run – in this case the OpenDCRE image hosted on the Vapor IO DockerHub.

`./start_opendcre.sh` the command to run in the container. this particular command is superfluous as it is the default command that is run by OpenDCRE, but was included here for completeness of the example.

DeviceBus Interfaces

At the heart of OpenDCRE is the notion of "device bus" (or "devicebus"), which is so-named due to the original single-purpose PLC bus, and can now be said to describe "devices and busses" supported by OpenDCRE. Currently, there are three devicebus interfaces supported by OpenDCRE: PLC, IPMI, and Redfish (beta).

PLC Device

New in version 1.0.0.

PLC (Power Line Communications) support was the first (and only) mode available in early (pre v1.0) versions of OpenDCRE. The PLC Device provides support for serial-based communication between OpenDCRE and the Vapor Chamber.

Supported Commands

The *test* and *service version* are supported by all devicebus types. Below are the commands which are supported for PLC Devices. See the *API Reference* for details on all commands.

Command	Supported
Version	True
Scan	True
Scan All	True
Read	True
Power	True
Asset	True
Boot Target	True
Chamber LED	True
LED	True
Fan	True
Host Info	True

Configuration

PLC Device configurations are specified under the `devices` field of the OpenDCRE *Configuration Options*. A simple example configuration is given below, followed by descriptions of the fields presented in the example.

```
{
  "devices": {
    "plc": {
      "from_config": "plc_config.json"
    }
  }
}
```

from_config The file which specifies the rack and device configurations for devices managed through OpenDCRE. See below for an example of these configurations.

config An alternative to `from_config` - this field allows one to specify the rack and device configurations in this configuration file as opposed to a separate one. Generally, it is recommended to use `from_config` over this, as it keeps things cleaner, but if only a few devices are being specified, it may be easier to define their configurations under this field.

As mentioned above, the `from_config` and `config` fields specify the device-specific configurations. The JSON example below could either be specified under the `config` field, or in the file specified by the `from_config` field.

```
{
  "racks": [
    {
      "rack_id": "rack_1",
      "lockfile": "/tmp/OpenDCRE.lock",
      "hardware_type": "emulator",
      "devices": [
        {
          "device_name": "/dev/ttyAMA0",
          "retry_limit": 3,
          "timeout": 0.25,
          "time_slice": 75,
          "bps": 115200
        }
      ]
    }
  ]
}
```

racks OpenDCRE is capable of managing multiple racks' worth of BMCs, so the top-level configuration parameter "racks" consists of a list of rack definitions (in the above example, only a single rack with rack_id of "rack_1" is specified).

rack_id For each rack configured with OpenDCRE, a "rack_id" must be specified to identify that rack. In the example above, "rack_1" is the rack_id. This is the same rack_id specified in OpenDCRE REST API commands. When multiple devicebus types are defined for an OpenDCRE configuration, devices in common rack_ids are merged together into the rack record in scan results for that rack. In other words, devices from multiple devicebus types may be assigned to the same rack in OpenDCRE, assuming the same rack_id is used in each of their configurations.

lockfile At the rack-level, a lockfile path and filename may be defined such that all devices belonging to that rack share a common lockfile, ensuring serial and exclusive access to the bus. *(This lockfile may also be shared with other racks and bus types when shared bus/hardware access must be serial across racks and bus types.)*

hardware_type Indicates whether hardware is emulated ("emulator") or "real". In the case of "emulator", device interface implementations may use an alternate code path (e.g. for testing or demonstration purposes) routed to an emulator, as opposed to taking physical hardware actions. When using OpenDCRE with emulator backing, "emulator" should be specified here, otherwise, when OpenDCRE is used with real hardware, "real" should be specified for hardware_type.

devices Within a given rack, one or more PLC devices may be specified for brokering bus access to the PLC bus. In most cases involving PLC, only a single device is present, corresponding to the PLC modem serial device and its configuration, however multiple devices can be supported (e.g. in the case of multiple PLC buses or modems in a single rack).

device_name The path and file name to the serial TTY device for PLC communications. When `hardware_type` is "emulator", this typically corresponds to the OpenDCRE-side of a socat-paired virtual serial connection (e.g. /dev/ttyVapor001). When `hardware_type` is "real", this corresponds to the physical serial device mapped into the OpenDCRE container for use with PLC for reading and writing.

retry_limit Configures the number of retries permitted (in case of line noise or bus errors) before an error is returned. The default should be sufficient in most cases. **(default: 3)**

timeout A decimal value indicating the time, in seconds, to wait for a response to an OpenDCRE PLC bus command before timing out. The default value is typically sufficient in physical hardware cases as well as with the OpenDCRE PLC emulator. **(default: 0.25)**

time_slice The time slice used during a scan command to enumerate all PLC devices on the PLC bus. This value is used to allow devices to use their internal board_id and the time slice value to determine which window to use in responding to the scan command. Users generally should not alter this value. **(default: 75)**

bps The bits per second configuration value to use for PLC communications on the PLC bus. This generally should not be modified by users. **(default: 115200)**

If a field is missing, or the PLC configuration file is improperly formatted, OpenDCRE PLC capabilities will not be available.

IPMI Device

New in version 1.1.0.

IPMI Devices allow users of OpenDCRE to issue LAN-based IPMI commands using the OpenDCRE REST API.

Supported Commands

The *test* and *service version* are supported by all devicebus types. Below are the commands which are supported for IPMI Devices. See the *API Reference* for details on all commands.

Command	Supported
Version	True
Scan	True
Scan All	True
Read	True
Power	True
Asset	True
Boot Target	True
Chamber LED	False
LED	True
Fan	True
Host Info	True

Requirements

- OpenDCRE must be connected to a wired LAN network that can reach all BMCs configured to be managed over OpenDCRE.
- Knowledge of BMC IP addresses, ports, usernames, and passwords (where applicable) required.

Changed in version 1.3.0: Previously, a custom IPMI interface was used which required the specification of authentication type, integrity type, and encryption type. Now, pyghmi is used as the IPMI interface, which does not expose customization for those parameters, thus they need no longer be specified in the configuration file.

Configuration

IPMI Device configurations are specified under the `devices` field of the OpenDCRE *Configuration Options*. A simple example configuration is given below, followed by descriptions of the fields presented in the example.

```
{
  "devices": {
    "ipmi": {
      "scan_on_init": true,
      "device_initializer_threads": 4,
      "from_config": "bmc_config.json"
    }
  }
}
```

from_config The file which specifies the rack and BMC configurations for BMCs managed through OpenDCRE. See below for an example of these configurations.

config An alternative to `from_config` - this field allows one to specify the rack and BMC configurations in this configuration file as opposed to a separate one. Generally, it is recommended to use `from_config` over this, as it keeps things cleaner, but if only a few BMCs are being specified, it may be easier to define their configurations under this field.

scan_on_init *(optional)* A flag which determines whether or not the IPMI Devices will perform a scan operation on device initialization, or if it will be deferred for later. Typically, it is a good idea to scan on initialization, as that is how the board record is created and how the devices off of the BMC are found. Deferring scan to a time post-initialization can be useful in testing or if there is high network latency and one does not want the slow initialization process to delay OpenDCRE startup. **(default: true)**

device_initializer_threads *(optional)* The number of threads to use when initializing IPMI Devices. Since IPMI devices use LAN communication, initializing multiple devices can be done in parallel. **(default: 1)**

As mentioned above, the `from_config` and `config` fields specify the BMC-specific configurations. The JSON example below could either be specified under the `config` field, or in the file specified by the `from_config` field.

```
{
  "racks": [
    {
      "rack_id": "rack_1",
      "bmcs": [
        {
          "bmc_ip": "192.168.1.110",
          "username": "ADMIN",
          "password": "ADMIN"
        },
        {
          "bmc_ip": "192.168.1.111",
          "bmc_port": 623,
          "username": "ADMIN",
          "password": "ADMIN",
          "hostnames": ["atom"],
          "ip_addresses": ["192.169.1.111"]
        }
      ]
    }
  ]
}
```

racks OpenDCRE is capable of managing multiple racks' worth of BMCs, so the top-level configuration parameter "racks" consists of a list of rack definitions (in the above example, only a single rack with rack_id of "rack_1" is specified).

rack_id For each rack configured with OpenDCRE, a "rack_id" must be specified to identify that rack. In the example above, "rack_1" is the rack_id. This is the same rack_id specified in OpenDCRE REST API commands. When multiple devicebus types are defined for an OpenDCRE configuration, devices in common rack_ids are merged together into the rack record in scan results for that rack. In other words, devices from multiple devicebus types may be assigned to the same rack in OpenDCRE, assuming the same rack_id is used in each of their configurations.

bmcs The "bmcs" field consists of a list of zero or more BMC configuration records. Each BMC configuration record corresponds to an individual BMC situated in the configured rack.

bmc_ip The IP address (or hostname) of the BMC being configured. It must be a string value and the BMC IP must also be accessible over LAN by the OpenDCRE service.

username The username used to connect to the BMC. For OpenDCRE to be able to fully control a remote server, the username should have sufficient permissions on the remote BMC.

password The password used to connect to the BMC for the given username.

bmc_port *(optional)* The UDP port number of the BMC. Must be specified as an integer. **(default: 623)**

hostnames *(optional)* A list of known hostnames for the remote system that may be used in place of the board_id of the BMC for OpenDCRE REST API requests. This list may be augmented by OpenDCRE in case of DCMI support, where DCMI may be used to get host identification as well.

At minimum, the contents of the "hostnames" list are returned in scan and host_info responses related to the given system.

ip_addresses *(optional)* A list of known IP addresses for the remote system that may be used in place of the board_id of the BMC for OpenDCRE REST API requests. This list may be augmented by OpenDCRE to include the bmc_ip (if not already included in this list), allowing access to any IPMI device via OpenDCRE REST API by using the BMC IP or known IP addresses in place of board_id. Contents of the "ip_addresses" list are returned in scan and host_info responses related to the given system.

If a field is missing, or the IPMI configuration file is improperly formatted, OpenDCRE IPMI capabilities will not be available.

Supported Devices

Currently, the supported devices for IPMI include:

- power
- system
- LED
- fan
- power supply
- temperature
- voltage

Tested BMCs

OpenDCRE v1.3 has been tested and verified to be compatible with IPMI 2.0 connections and commands for the following BMCs:

- ASpeed AST2400 (via HPE CL7100)
- Nuvoton WPCM450RA0BK (via SuperMicro X7SPA-HF)
- ASpeed AST2050 (via Tyan S8812)
- ASpeed AST1250 (via Freedom)

The OpenDCRE community welcomes testing and bug reports against other BMCs and system types.

Redfish Device

New in version 1.3.0.

Warning: Redfish support is in beta as of OpenDCRE v1.3.0

Redfish Devices map Redfish schema into OpenDCRE, allowing for LAN-based Redfish commands using the OpenDCRE REST API.

Supported Commands

The *test* and *service version* are supported by all devicebus types. Below are the commands which are supported for Redfish Devices. See the *API Reference* for details on all commands.

Command	Supported
Version	True
Scan	True
Scan All	True
Read	True
Power	True
Asset	True
Boot Target	True
Chamber LED	False
LED	True
Fan	True
Host Info	True

Configuration

Redfish Device configurations are specified under the `devices` field of the OpenDCRE *Configuration Options*. A simple example configuration is given below, followed by descriptions of the fields presented in the example.

```
{
  "devices": {
    "redfish": {
      "scan_on_init": true,
      "device_initializer_threads": 4,
      "from_config": "redfish_config.json"
    }
  }
}
```

from_config The file which specifies the rack and device configurations for devices managed through OpenDCRE. See below for an example of these configurations.

config An alternative to `from_config` - this field allows one to specify the rack and device configurations in this configuration file as opposed to a separate one. Generally, it is recommended to use `from_config` over this, as it keeps things cleaner, but if only a few devices are being specified, it may be easier to define their configurations under this field.

scan_on_init *(optional)* A flag which determines whether or not the Redfish Devices will perform a scan operation on device initialization, or if it will be deferred for later. Typically, it is a good idea to scan on initialization, as that is how the board record is created and how the devices are found. Deferring scan to a time post-initialization can be useful in testing or if there is high network latency and one does not want the slow initialization process to delay OpenDCRE startup. **(default: true)**

device_initializer_threads *(optional)* The number of threads to use when initializing Redfish Devices. Since Redfish devices use LAN communication, initializing multiple devices can be done in parallel. **(default: 1)**

As mentioned above, the `from_config` and `config` fields specify the device-specific configurations. The JSON example below could either be specified under the `config` field, or in the file specified by the `from_config` field.

```
{
  "racks": [
    {
      "rack_id": "rack_1",
      "servers": [
        {
          "redfish_ip": "192.168.1.110",
          "redfish_port": "5040",
          "timeout": 5,
          "username": "ADMIN",
          "password": "ADMIN",
          "hostnames": ["redfish-server-1"],
          "ip_addresses": ["192.168.1.110"]
        }
      ]
    }
  ]
}
```

racks OpenDCRE is capable of managing multiple racks' worth of servers, so the top-level configuration parameter "racks" consists of a list of rack definitions (in the above example, only a single rack with rack_id of "rack_1" is specified).

rack_id For each rack configured with OpenDCRE, a "rack_id" must be specified to identify that rack. In the example above, "rack_1" is the rack_id. This is the same rack_id specified in OpenDCRE REST API commands. When multiple devicebus types are defined for an OpenDCRE configuration, devices in common rack_ids are merged together into the rack record in scan results for that rack. In other words, devices from multiple devicebus types may be assigned to the same rack in OpenDCRE, assuming the same rack_id is used in each of their configurations.

servers The servers field consists of a list of zero or more Redfish server configuration records. Each Redfish configuration record corresponds to an individual Redfish server situated in the configured rack.

redfish_ip The IP address (or hostname) of the Redfish server being configured. The Redfish IP must also be accessible over LAN by the OpenDCRE service.

redfish_port The port which the Redfish server is listening on.

timeout The timeout, in seconds, for the HTTP request being made to the Redfish server before an error is raised.

username The username used to connect to the Redfish server.

password The password used to connect to the Redfish server for the given username.

hostnames A list of known hostnames for the remote system that may be used in place of the board_id for the Redfish server for OpenDCRE REST API requests.

ip_addresses A list of known IP addresses for the remote system that may be used in place of the board_id for the Redfish server for OpenDCRE REST API requests.

If a field is missing, or the Redfish configuration file is improperly formatted, OpenDCRE Redfish capabilities will not be available.

Emulators

OpenDCRE comes with pre-built emulators for each supported devicebus type so that it can emulate API commands and functionality in the absence of supported hardware. This is especially useful for testing and experimenting with OpenDCRE.

PLC Emulator

The PLC Emulator runs as a background process in the OpenDCRE container itself. It uses socat to create a connected pair of virtual TTY devices that can be used to simulate serial communications without hardware. The main difference between the emulated PLC comms and hardware PLC comms is that the emulator does not require the additional steps of configuring the serial device and initializing the SIG60 PLC modem.

The emulator itself is a primitive Python process that is provided a configuration file on startup to map board/device ids to raw packet readings. These packet readings are returned to the device on the other end of the virtual serial connection. Faults, repeated values, cycling values, or no value returns are supported by the PLC emulator through its config file. State can also be preserved in cases where an incoming command mutates state (e.g. turns on an LED) - state honoring may be enabled/disabled in the emulator configuration for a board/device.

Configuration Example

```
{
  "boards": [
    {
      "board_id": "00000001",
      "firmware_version": "OpenDCRE Emulator v1.0.0 - Standalone Server",
      "devices": [
        {
          "host_info": {
            "repeatable": true,
            "responses": [
              "i10.10.1.16,htest-server0"
            ]
          },
          "has_state": true,
          "boot_target": "B0",
          "pxe" : "B1",
          "no_override": "B2",
          "hdd": "B0",
          "asset_info": {
            "repeatable": true,
            "responses": [
              "Quanta,0001,Winterfell,S1234567,rack mount chassis,P1234567,S1234567,A1234567,Quanta,
            ]
          },
          "device_type": "system",
          "device_id": "0001"
        },
        {
          "read": {
            "repeatable": true,
            "responses": [
              4100, 4100, 4000, 4000, 3900, 3900, 3800, 3800, 3700, 3700,
              3800, 3800, 3900, 3900, 4000, 4000, 4100, 4100, 4200, 4200
            ]
          },
          "write": {
            "repeatable": true,
            "responses": [
              "W1"
            ]
          },
          "device_type": "fan_speed",
          "device_id": "0002"
        },
        {
          "read": {
            "repeatable": true,
            "responses": [
              4100, 4100, 4000, 4000, 3900, 3900, 3800, 3800, 3700, 3700,
              3800, 3800, 3900, 3900, 4000, 4000, 4100, 4100, 4200, 4200
            ]
          },
          "write": {
            "repeatable": true,
            "responses": [
              "W1"
            ]
          },
          "device_type": "fan_speed",
          "device_id": "0003"
        },
        {
          "device_id": "0004",
          "device_type": "power",
          "has_state": true,
          "on": [
            "0,10000,0,0", "0,11000,0,0", "0,12000,0,0", "0,13000,0,0",
            "0,14000,0,0", "0,15000,0,0", "0,14000,0,0", "0,13000,0,0",
            "0,12000,0,0", "0,11000,0,0"
          ],
          "off": "64,0,0,0",
          "power": [
            "0,10000,0,0", "0,11000,0,0", "0,12000,0,0", "0,13000,0,0",
            "0,14000,0,0", "0,15000,0,0", "0,14000,0,0", "0,13000,0,0",
            "0,12000,0,0", "0,11000,0,0"
          ]
        },
        {
          "device_id": "0005",
          "device_type": "led",
          "has_state": true,
          "read": 0,
          "write": 0,
          "on": 1,
          "off": 0
        },
        {
          "read": {
            "repeatable": true,
            "responses": [
              28.78, 29.77, 30.75, 31.84, 32.82, 33.81, 34.89, 35.88, 36.96, 37.94,
              38.93, 40.21, 41.27, 42.33, 43.39, 44.45, 45.61, 46.57, 47.63, 48.69,
              49.75, 48.69, 47.63, 46.57, 45.61, 44.45, 43,39, 42.33, 41.27, 40.21,
              38.93, 37.94, 36.96, 35.88, 34.89, 33.81, 32.82, 31.84, 30.75, 29.77
            ]
          },
          "device_type": "temperature",
          "device_id": "2000"
        },
        {
          "read": {
            "repeatable": true,
            "responses": [
              28.78, 29.77, 30.75, 31.84, 32.82, 33.81, 34.89, 35.88, 36.96, 37.94,
              38.93, 40.21, 41.27, 42.33, 43.39, 44.45, 45.61, 46.57, 47.63, 48.69,
              49.75, 48.69, 47.63, 46.57, 45.61, 44.45, 43,39, 42.33, 41.27, 40.21,
              38.93, 37.94, 36.96, 35.88, 34.89, 33.81, 32.82, 31.84, 30.75, 29.77
            ]
          },
          "device_type": "temperature",
          "device_id": "4000"
        }
      ]
    }
  ]
}
```

Configuration Fields

boards A list of boards configured for the emulator, where a single board configuration would represent a single hardware board that should exist.

board_id The internal id for a single board. Board Ids in OpenDCRE have a 4 byte width and should be expressed in the config as a 4-byte hex string. Board Ids should be unique across all device instances. For PLC, the board id range starts at 0x00000000.

firmware_version The version string for the board, which would be returned by the OpenDCRE "version" command.

devices A list of all device configurations which are associated with that given board.

repeatable A flag which denotes that the given responses should repeat. This means that when the emulator has cycled through all of the responses in the responses list, it will return to the beginning of the list. If this is set to `false`, upon reaching the end of the responses list, the emulator will not return data, causing an error to be raised in OpenDCRE (as the emulator will not respond).

responses A list of canned responses for the emulator to return.

host_info The response(s) to return on a system "host info" command.

asset_info The response(s) to return on a system "asset info" command.

read The response(s) to return on a "read" command.

write The response(s) to return on a "write" command.

on The response(s) to return on a "power on" command.

off The response(s) to return on a "power off" command.

power The response(s) to return on a "power status" command.

has_state If true, then state information is preserved relative to the command (e.g. "on" or "off" for power), in which case subsequent reads retrieve a response relative to the persisted state. When state is undefined, the default response (e.g. "power") for the command is returned. When `has_state` is false, the response relative to an incoming command is returned (e.g. the response for "on" for a power "on" command).

boot_target Indicates the response sent back for a "get" of boot target (B0 == no_override, B1 == pxe, B2 == hdd).

pxe The response sent when boot target of PXE is set.

no_override The response sent when boot target of no_override is set.

hdd The response sent when boot target of HDD is set.

device_type Indicates the type of device that a device entry represents. This is also the `device_type` reported back in OpenDCRE REST API scan results. Valid device types include:

- `thermistor`
- `power`
- `humidity`
- `pressure`
- `led`
- `system`
- `fan_speed`
- `temperature`

Changed in version 1.2: In previous releases, a device type of `none` indicated that no device is present at a given `device_id` on the given board, and may be ignored. In OpenDCRE v1.2 the `none` device type has been removed.

device_id The internal device id of the device being configured, expressed as a 2-byte numeric value as a hex string. In most cases, a device id of "0001" is sufficient.

Additional Information on Configuration Fields

Device Type

A field corresponding to the action supported for a given device type is required. A map of device types to supported actions is below:

Device Type	Action Supported
`thermistor`	`read`
`temperature`	`read`
`power`	`power`
`humidity`	`read`
`pressure`	`read`
`led`	`read`, `write`
`fan_speed`	`read`, `write`
`system`	`asset info`, `boot target`

Read

For the `read` action's field in the OpenDCRE emulator configuration, two fields may be configured relating to the responses returned from a read command for the given device.

First, the `repeatable` field may be set to true or false, depending on whether it is desirable for the list of responses set in the responses field to repeat in a round-robin fashion, or if a device should stop returning data after its response list has been exhausted.

The `responses` field is a list of zero or more values that may be returned for a given read command. The raw values are converted (where necessary) by the built-in OpenDCRE conversion functions, based on the given `device_type`.

When a list of values is provided for responses, the emulator iterates sequentially through the items in that list, until the list is exhausted (if repeatable is set to "true", then the emulator returns to the beginning of the list).

An empty responses list means the device returns no data, which translates to a 500 error for the read command at the OpenDCRE REST API level (useful for simulating errors). To always return the same single value, a responses list with a single element, and repeatable set to "true" will suffice.

Read Response Format

The table below describes the response format for each device type for `read` commands to the emulator.

Device Type	Format
`thermistor`	integer, converted by OpenDCRE
`temperature`	numeric, sent back as numeric value (e.g. 28.78)
`humidity`	numeric, converted by OpenDCRE
`led`	integer, `1` is `on` and `0` is `off`; all other values are errors
`fan_speed`	integer, sent back as integer value (e.g. 4100)

Values that do not conform to the above formats will result in errors to `read` requests made to the emulator, as they would on the device bus.

Write

For the `write` action's field in the OpenDCRE emulator configuration, two fields may be configured, relating to the responses returned from a write command for the given device. The fields are laid out and function in the same manner as `read` fields.

Write Response Format

The table below describes the response format for each device type for `write` commands to the emulator.

Device Type	Format
`led`	string - `W1` is successful, while `W0` is unsuccessful; all other values are errors.
`fan_speed`	string - `W1` is successful, while `W0` is unsuccessful; all other values are errors.

Values that do not conform to the above formats will result in errors to `write` requests made to the emulator, as they would on the device bus.

Writing to a device from OpenDCRE to the emulator does not currently result in any state change for a corresponding device in the emulator. That functionality may be added in a future release.

Power

For the `power` action's field in the OpenDCRE emulator configuration, similar fields are present - repeatable and responses.

For every power command (e.g. `on`/`off`/`cycle`/`status`) issued to a power device in the OpenDCRE emulator, a response is returned from the responses list, which may be repeatable or non-repeatable. The values in the responses list correspond to power status values returned over PMBUS from the hot swap controller on an OCP server, and are expressed as an integer value in the emulator configuration (see example above). OpenDCRE converts the raw response to a friendly power status result using its built-in conversion functions.

Other Notes

The OpenDCRE emulator is also used for testing purposes, and additional emulator configurations may be found under the `/opendcre/opendcre_southbound/tests/data` directory of the OpenDCRE Docker container.

An invalid emulator configuration will cause the OpenDCRE emulator to fail to start or function properly.

Additional features of the emulator that may be used by advanced users or hardware/protocol developers include:

- Ability to send back raw bytes for responses to `scan`, `version`, `read`, `write`, and `power` commands. In tests, this can be seen where a list (or list of lists) of integer values is specified for a given response. Special sentinel values (999, 10xx) are used to place sequence numbers and checksums into the packet stream.
- Ability to support command retries in cases of invalid packets, line noise, etc.
- Ability to support 'scan-all' command and retries using time-division multiplexing; success and failure scenarios may be implemented for various configurations. See the `test-scanall` tests.

Running the Emulator

To run the PLC emulator, simply specify the startup script for the PLC emulator.

```
docker run -p 5000:5000 vaporio/opendcre ./start_opendcre_plc_emulator.sh
```

or, if using docker-compose:

```
opendcre:
  image: vaporio/opendcre
  command: ./start_opendcre_plc_emulator.sh
  ports:
    - 5000:5000
```

The examples above will start the emulator with the default configuration file, found at `/opendcre/opendcre_southbound/emulator/plc/data/example.json`. To specify different emulator configurations, simply pass that file as an argument to the emulator start script. Note that if the non-default emulator configuration is not built into the OpenDCRE image, it will need to be volume-mounted in, e.g.

```
docker run \
    -p 5000:5000 \
    -v `pwd`/emulator_config:/opendcre/new_emulator_config.json \
    vaporio/opendcre \
    ./start_opendcre_plc_emulator.sh /opendcre/new_emulator_config.json
```

IPMI Emulator

For IPMI communications, there is an IPMI emulator which exists as a Dockerized Python multithreaded UDP server that accepts inbound UDP IPMI packets, processes them, and returns a response based on the emulator configuration and internal state.

The IPMI Emulator, which is perhaps better described as a BMC Emulator, is stateful where applicable. For example, one can set the boot target or LED state on the emulator and a subsequent examination of either should reveal the state to be the new values it was set to.

The IPMI Emulator is primarily designed to work with pyghmi, as that is the library used within OpenDCRE to issue IPMI commands. To accommodate pyghmi, the emulator supports: - HMAC-SHA1-96 integrity checking - RAKP_HMAC_SHA1 authentication - AES_CBC_128 encryption. The encrypted mode can be tested using pyghmi or ipmitool.

For ease of use and simplicity for debugging, it also supports no authentication/encryption which allows all bytes to be examined (e.g. with Wireshark). This unencrypted mode can be tested using ipmitool.

The IPMI emulator is largely just a framing device which unpacks incoming requests and packs outgoing responses. The actual logic to handle commands is often simple, typically just returning values either from internal state or emulator configuration.

Configuration Example

The IPMI Emulator configuration lives in the `opendcre/opendcre_southbound/emulator/ipmi/data` directory and is built into the emulator's Docker image (at the same path, starting at root). Configurations can be changed by either - Modifying the source configurations and rebuilding the Docker image - Mounting in configuration overrides with Docker volumes.

There are four configuration files associated with the IPMI emulator

Note: All of the raw bytes specified in these config files were taken off the wire (using Wireshark) when communicating with a real BMC.

bmc.json

bmc.json contains the configurations for the mock BMC that is the IPMI emulator. It allows the specification of device info, chassis info, channel authentication capabilities, and dcmi configurations. Generally, the configurations specified in this file are the raw bytes that make up the IPMI responses.

```
{
  "device": {
    "device_id": "20",
    "device_revision": "01",
    "device_availability": "03",
    "minor_firmware_revision": "16",
    "ipmi_version": "02",
    "additional_device_support": "bf",
    "manufacturer_id": 47488,
    "product_id": 2566
  },
  "chassis": {
    "current_power_state": "01",
    "last_power_event": "00",
    "misc_state": "40",
    "bootdev": "no_override"
  },
  "channel_auth_capabilities": {
    "channel": "01",
    "version_compatibility": "96",
    "user_capabilities": "06",
    "supported_connections": "03",
    "oem_id": 21317,
    "oem_auxiliary_data": "00"
  },
  "capabilities": {
    "hpm": ["81", "b4", "cb", "20", "08", "3e", "c1", "d9"],
    "picmg": ["81", "b4", "cb", "20", "10", "00", "c1", "0f"],
    "vita": ["81", "b4", "cb", "20", "14", "00", "c1", "0b"]
  },
  "dcmi": {
    "power": {
      "current_watts": [185, 188, 186, 189, 188, 192, 195, 199, 210, 211, 213, 211, 212],
      "min_watts": 150,
      "max_watts": 250,
      "avg_watts": 200,
      "reporting_interval_ms": 305000
    },
    "capabilities": {
      "1": ["dc", "01", "05", "02", "00", "01", "07"],
      "2": ["dc", "01", "05", "02", "00", "00", "00", "00", "00"],
      "3": ["dc", "01", "05", "02", "20", "00"],
      "4": ["dc", "01", "05", "02", "ff", "ff", "ff"],
      "5": ["dc", "01", "05", "02", "01", "00"]
    }
  }
}
```

fru.json

fru.json contains the raw configuration data for the mock BMC's FRU. The config file specifies the FRU inventory area and the raw data that makes up the FRU.

```
{
  "inventory_area": 1024,
  "device_access": 0,
  "data": [
    "01", "00", "00", "01", "06", "00", "00", "f8", "01", "05", "00",
    "00", "00", "00", "ca", "53", "75", "70", "65", "72", "6d", "69",
    "63", "72", "6f", "c0", "ca", "20", "20", "20", "20", "20", "20",
    "20", "20", "20", "20", "c0", "c0", "c1", "00", "00", "00", "00",
    "00", "00", "fc", "00", "01", "03", "00", "c0", "c0", "c0", "c0",
    "ca", "20", "20", "20", "20", "20", "20", "20", "20", "20", "20",
    "c0", "c0", "c1", "00", "00", "b1"
  ]
}
```

sdr.json

sdr.json contains the raw configuration data for the mock BMC's SDR. This includes the version, record count, free space, latest addition, latest erase, and operation support. The configuration for the actual SDR records is not specified in this file, but in *sdr_entries.json*.

```
{
  "sdr_version": 1.5,
  "record_count": 21,
  "free_space": 1663,
  "latest_addition_ts": 0,
  "latest_erase_ts": 0,
  "operation_support": "2f"
}
```

sdr_entries.json

sdr_entries.json is the config file where all device records belonging to the SDR are defined. The number of devices defined in this config should match the device count specified in *sdr.json*. For each record, an id, sensor type, data, readings, event messages, and threshold comparison field should be specified. The sensor type field is not used by the IPMI emulator, but is used as a convenient means of labeling the record with a human-readable description.

```
{
  "records": [
    {
      "id": "0000",
      "sensor_type": "System Temp",
      "data": [
        "04", "00", "51", "01", "36", "20", "00", "11", "07", "01", "7d", "68",
        "01", "01", "80", "7a", "80", "7a", "3f", "3f", "80", "01", "00", "00",
        "01", "00", "00", "00", "00", "00", "07", "2d", "4a", "fc", "7f", "80",
        "4f", "4d", "4b", "f7", "f9", "fb", "02", "02", "00", "00", "00", "cb",
        "53", "79", "73", "74", "65", "6d", "20", "54", "65", "6d", "70"
      ],
      "readings": [
        49, 49, 48, 47, 48
      ],
      "event_messages": "c0",
      "threshold_comparison": ["c0"]
    },
    {
      "id": "0047",
      "sensor_type": "CPU Temp",
      "data": [
        "47", "00", "51", "01", "33", "20", "00", "12", "03", "01", "7f", "68",
        "01", "01", "80", "7a", "80", "7a", "3f", "3f", "80", "01", "00", "00",
        "01", "00", "00", "00", "00", "00", "07", "1e", "59", "fc", "7f", "80",
        "5f", "5a", "55", "f5", "f8", "fb", "02", "02", "00", "00", "00", "c8",
        "43", "50", "55", "20", "54", "65", "6d", "70"
      ],
      "readings": [
        41, 40, 41, 41
      ],
      "event_messages": "c0",
      "threshold_comparison": ["c0"]
    },
    {
      "id": "008a",
      "sensor_type": "CPU FAN",
      "data": [
        "8a", "00", "51", "01", "32", "20", "00", "41", "1d", "01", "7d", "68",
        "04", "01", "95", "7a", "95", "7a", "3f", "3f", "00", "12", "00", "00",
        "b9", "00", "00", "c0", "00", "01", "07", "80", "aa", "14", "ff", "00",
        "b2", "af", "ac", "10", "11", "12", "01", "01", "00", "00", "00", "c7",
        "43", "50", "55", "20", "46", "41", "4e"
      ],
      "readings": [
        34, 34, 35, 34, 33
      ],
      "event_messages": "c0",
      "threshold_comparison": ["c0"]
    },
    ...
    (abridged for brevity)
  ]
}
```

Getting the Emulator

Since the IPMI Emulator is a standalone image, it needs to either be pulled from DockerHub, or built from Dockerfile.

From DockerHub,

```
docker pull vaporio/ipmi-emulator-x64
```

From Dockerfile, first navigate to `opendcre_southbound/emulator/ipmi`. Then, you can build the IPMI emulator image with

```
make build-x64
```

Running / Using the Emulator

Running the emulator in isolation is straightforward enough. Once you have the image, you can run it either with docker:

```
docker run --name ipmi-emulator -p 623:623/udp vaporio/ipmi-emulator-x64
```

or with docker-compose

```
docker-compose -f ipmi-emulator.yml up --build -d ipmi-emulator
```

where `ipmi-emulator.yml` contains

```
ipmi-emulator:
  container_name: ipmi-emulator
  image: vaporio/ipmi-emulator-x64
  command: ./start_ipmi_emulator.sh
  ports:
    - 623:623/udp
```

While other emulators (e.g. the PLC emulator) are built in to OpenDCRE and can be run from the same container, the IPMI emulator must be run from a separate container, as shown above.

This is done in part for emulator isolation, but also because it allows for more flexible test setups. For instance, with the emulator running in a separate container it is possible to spin up multiple emulator instances, each with their own configuration, to emulate OpenDCRE performance against different BMC models. Additionally, with docker-compose, OpenDCRE can have multiple proxies to the same emulator to simulate a full rack, cluster, or multi-cluster of BMCs.

Warning: When using the IPMI emulator in a proxied fashion, where multiple composefile links point to the same emulator, the number of requests issued against the emulator can become an issue, especially under high network latency, where the requests back up and time out.
When run locally, this had caused the emulator to freeze up and communications between OpenDCRE and the emulator fail. One solution to this is to run the IPMI Emulator on a separate instance/machine when there will be heavy load placed upon it. This will ensure that it is given enough machine resources to operate at full capacity - although network latency can then become an issue.
Running the emulator on a separate instance/machine is recommended even without heavy load, for stability and performance.

Above, we describe how to run an IPMI emulator. Some additional configuration will need to happen with OpenDCRE in order for it to register the IPMI emulator as a usable interface.

The networking between the emulator and OpenDCRE is determined by the BMC config used by OpenDCRE. For example, if there were a BMC config containing the record:

```
{
  "bmc_ip": "localhost",
  "username": "ADMIN",
  "password": "ADMIN"
}
```

we would want the emulator to be running on the same machine as OpenDCRE, as localhost should resolve to the emulator.

The containers can also be linked in the composefile, if running on the same machine, so we can reference the emulator using the container name as a hostname:

```
{
  "bmc_ip": "ipmi-emulator",
  "username": "ADMIN",
  "password": "ADMIN"
}
```

Of course, a plain IP for the machine running the emulator can be supplied as the bmc_ip without any need to create container links.

An example (abridged) composefile with the two containers linked is as follows:

```
opendcre:
  image: vaporio/opendcre-core-x64
  command: ./start_opendcre.sh
  ports:
    - 5000:5000
  links:
    - ipmi-emulator

ipmi-emulator:
  image: vaporio/ipmi-emulator-x64
  ports:
    - 623:623/udp
```

Note that here, the OpenDCRE instance was started without running any other emulator. While it is possible (and fine) to run the IPMI emulator alongside any of the serial emulators, keeping things isolated to IPMI-only for testing is usually prudent.

Redfish Emulator

Warning: Redfish support is in beta as of OpenDCRE v1.3.0

Like the IPMI emulator, the Redfish Emulator is a standalone Dockerized python application. It runs a simple Flask webserver that serves up statically defined configuration data. It supports the basic Redfish commands and is stateful, for operations where state can be preserved (e.g. turning an LED on). By default, the Redfish emulator runs on port 5040. This can be changed by updating the Dockerfile and specifying the correct port mapping at run time.

Configuration

The configuration files which make up the Redfish emulator backend are too numerous to include here - instead, see the Redfish mockups which the configuration hierarchy is based off of.

To re-configure the Redfish emulator, either a new emulator image can be built with the new configuration placed in the emulator's *Resources* directory, or it can be volume mounted in over the emulator's *Resources* directory.

Getting the Emulator

Since the Redfish Emulator is a standalone image, it needs to either be pulled from DockerHub, or built from Dockerfile.

From DockerHub,

```
docker pull vaporio/redfish-emulator-x64
```

From Dockerfile, first navigate to `opendcre_southbound/emulator/redfish`. Then, you can build the Redfish emulator image with

```
make build-x64
```

Running the Emulator

Running the Redfish emulator is simple, given that the desired configurations (whether they be the default or custom built-in/volume-mounted configurations) are correctly placed in the image:

```
docker run -p 5040:5040 vaporio/redfish-emulator-x64
```

Testing

OpenDCRE is well-tested with hundreds of test cases that can be run. OpenDCRE tests must be run from the source code (see *Getting OpenDCRE*). All of the tests can be found under the `opendcre_southbound/tests` directory.

OpenDCRE tests are made up of four somewhat distinct parts:

1. The test runner
2. The test configuration
3. The test suite
4. The test cases

Test Runner

In `opendcre_southbound/tests`, there is a Makefile – this is the test runner. The Makefile contains recipes to run all of the tests OpenDCRE has. Tests can be run at a suite-level, or in groups of suites (e.g. all tests, tests for a given devicebus type, etc). Running all OpenDCRE tests is as simple as

```
make test-x64
```

Testing for only a single devicebus type can be done by adding the device type suffix, e.g. for PLC

```
make test-x64-plc
```

for IPMI

```
make test-x64-ipmi
```

and for Redfish

```
make test-x64-redfish
```

See the Makefile for more recipes and more information about how to run the tests.

Test Configuration

Each test in OpenDCRE is run out of a Docker container – fitting, since OpenDCRE runs out of a Docker container. This gives us an easy and uniform way to do unit testing and integration testing. The tests are orchestrated using docker-compose, and as such, each test suite will need to have its own compose file configuration. These compose files can be found in the `opendcre_southbound/tests/_composefiles` directory. Below is an example composefile configuration, followed by a brief explanation.

```
test-container-x64:
  container_name: test-container-x64
  build: ../../../..
  dockerfile: dockerfile/Dockerfile.x64
  command: bash -c "sleep 15 && python ./opendcre_southbound/tests/test-plc-endpoints.py"
  links:
    - opendcre-southbound-test-container

opendcre-southbound-test-container:
  build: ../../../..
  dockerfile: dockerfile/Dockerfile.x64
  command: ./start_opendcre_plc_emulator.sh ./opendcre_southbound/emulator/plc/data/test_bus.json
  expose:
    - 5000
  volumes:
    - ../../data/plc_override_config.json:/opendcre/override/config.json
  environment:
    - VAPOR_DEBUG=true
```

In the example above, we are performing an integration test on the OpenDCRE REST API with PLC backing (via the PLC emulator). In it, we have two containers that will run, “test-container-x64”, the container that will run the actual test suite, and “opendcre-southbound-test-container”, the OpenDCRE instance running with the PLC emulator backing.

Note: All containers which run the actual test cases should be named “test-container-x64”, since this name is used in the Makefile runner to attach to that container, allowing us to see the test results in the console.

Both test container and OpenDCRE container are built from the same Dockerfile - this is just for convenience since all of the test dependencies already exist in the OpenDCRE image.

The test container runs a test suite after a sleep. Not all tests need a sleep period, but they are often included to allow OpenDCRE to come up and fully configure before the tests start running against it.

Finally, we set the `VAPOR_DEBUG` environment variable to `true` - this enables debug logging in OpenDCRE. This isn’t necessary, but if a test does fail, it makes it eaiser to find the root of the failure.

Test Suite

As seen above in the compose file, the test suite is defined in the `opendcre_southbound/tests` directory. In the same directory, there should be a subdirectory with a name corresponding to the name of the python file that is the test suite. The subdirectory contains the test cases which make up the suite. The suite acts only to aggregate and run the test cases.

Test Cases

The test cases are the actual test code that is run. It uses Python's unittest package to define the tests in the test cases. As mentioned in the previous section, these are aggregated into a suite for running, so the test cases need not be contained to a single file, and are in fact often broken up into multiple files for clarity and organization.

Debugging

In the case of OpenDCRE failures or errors, it is helpful to know how some basic debugging steps.

Startup Errors

As covered in the subsequent sections here, OpenDCRE logs out to files within the container. One exception to this is for errors on container startup. In addition to logging out to file, it logs out to stderr of the container (pid 1), so it is accessible via `docker logs`. If a startup error should occur, the OpenDCRE container should terminate. In this case, it is often prudent to check the docker logs first to see if there is any information pertaining to a startup error.

```
docker logs opendcre
```

A startup error likely will only happen if there is a serious misconfiguration, or if building a custom OpenDCRE image, something was changed to break the initialization process.

Enabling Debug Logging

By default, production logging is enabled (logging at an ERROR level). To run things in "debug" mode, where DEBUG level logs are collected, simply run the container with the environment variable `VAPOR_DEBUG` set to `true`. This can be done in the docker command

```
docker run -p 5000:5000 -e VAPOR_DEBUG=true vaporio/opendcre
```

or via composefile

```
opendcre:
  image: vaporio/opendcre
  ports:
    - 5000:5000
  environment:
    - VAPOR_DEBUG=true
```

With debug logging enabled, there will be two sets of logs captured – the error logs (same as the production logs), and the debug logs.

Examining Log Files

There are two primary methods for accessing a container's logs: `docker exec` and `docker cp`.

docker exec

Using `docker exec` requires the container to be running. If the container has terminated and you need to get at the logs, this is not the method that should be used. To exec into a container interactively,

```
docker exec -ti <name or id of container> /bin/bash
```

This will drop you into the working directory of the container, `/opendcre`. From there, navigate to `/logs`, where all of the container logs are kept.

docker cp

Using `docker cp` can be done when the container is running or when it has terminated. It is used to copy the logs from the container file system to the host file system.

```
docker cp <name or id of container>:/logs <host copy destination>
```

This will place the log files on the host system at the specified location.

Troubleshooting

This section contains information on troubleshooting, common gotchas, and generally things to watch out for.

Testing the Service

A good practice is to hit the *test* endpoint after starting up a service. It can also be useful in ensuring that a service is still running. It will only return "ok" if the service is up and running, but note that an "ok" response from the test endpoint does **not** indicate the lack of errors elsewhere - it only means that the Flask application within the Docker container is running and that it is reachable.

Raising an Issue

If you come across an error or issue with OpenDCRE or just have a question/suggestion about it, please raise an issue for it!

If raising an issue around an error, please include as much context information around it as possible.

Gotchas

scan results unavailable on init

Particularly in cases when there are many devices configured, or where there is high network latency when configuring LAN Devices, one may observe that the initial startup takes some time and scan results are not available. OpenDCRE attempts to enumerate remote devices (e.g. BMCs for IPMI) on init by default, so that it can cache the results for subsequent commands. As such, the initialization process may take a few minutes.

To help mitigate this, some configuration options have been added around LAN-based devices, both for multi-threaded device initialization, and deferring scan to a time post-initialization.

If can results are unavailable for an extended amount of time, or just to validate that there are no errors while the initial scan takes place, one can examine the OpenDCRE log file, as described in the *Debugging* section.

Release Notes

v1.3.0

February 21, 2017

The OpenDCRE 1.3.0 release is another significant release which brings many changes to the OpenDCRE code base. Along with significant code refactoring, cleanup, documentation, and testing, this release brings in Redfish support.

Note: Redfish support should be considered a beta feature as of v1.3.0

Changelog

- Generalization of the underlying devicebus model. This makes it easier to add support for new protocols / devices moving forward.
- Added command dispatching from OpenDCRE endpoints to the new underlying devicebus model.
- Improvements to OpenDCRE configuration which allow for default and override configs.
- Switched internal IPMI back-end from custom C implementation to OpenStack's pyghmi
- [BETA] Redfish support in OpenDCRE
  - Standalone Redfish Emulator
  - Redfish Device integration into OpenDCRE
  - Test cases for the emulator as well as OpenDCRE configured under Redfish
- Various bug fixes and performance fixes.
- Improvements to code organization, formatting, and documentation.
- Dockerfile optimizations.
- Additional test cases added and existing test cases expanded.

Contributors

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- Erick Daniszewski, Vapor IO
- Matthew Hink, Vapor IO
- Klemente Gilbert-Espada, Vapor IO
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v1.2.0

March 5, 2016

The OpenDCRE v1.2.0 release is a significant release, adding a large set of new features to OpenDCRE.

This release provides a long-awaited major update to the original OpenDCRE v1.x codebase, and has excellent feature, test, and usability enhancements.

Changelog

- IPMI 2.0 support added to IPMI bridge
- Added support via PLC and IPMI for
  - *fan* command (fan control)
  - *led* command (chassis "identify" LED control)
  - *location* command (physical and intra-chassis location)
  - *asset* command (asset information)
  - *boot_target* command (boot target selection)
  - *temperature*, *humidity*, *fan_speed* sensor support added
- Normalization of OpenDCRE API command layout for consistency and future functionality
- PLC communications (devicebus_interfaces) for v1 RPI HAT finalized
- Emulator enhancements for new functionality
- Improvements to code organization, PEP8 compliance, documentation
- Testing via docker-compose (supported on RPI and Linux/MacOS)

Contributors

- **Andrew Cencini, Vapor IO (maintainer)**
  - IPMI, PLC, code, test enhancements
- **Klemente Gilbert-Espada, Vapor IO (docs, contributor)**
  - RPI `pyserial` bugfix, Sphinx documentation
- **Erick Daniszewski, Vapor IO (contributor)**
  - Test enhancements, bugfixes

Special thanks to early adopters and testers of OpenDCRE.

Glossary

OpenDCRE The Open Data Center Runtime Environment

devicebus A term which describes devices (e.g. IPMI device) and busses (e.g. PLC bus), synonymous with "device bus".

PLC Power line communications

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Jonathan Jacobs, Jonathan Lange, Julian Berman, Jürgen Hermann, Kevin Horn, Kevin Turner,
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                            VERSION 2

A. HISTORY OF THE SOFTWARE
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Python was created in the early 1990s by Guido van Rossum at Stichting
Mathematisch Centrum (CWI, see http://www.cwi.nl) in the Netherlands
as a successor of a language called ABC.  Guido remains Python's
principal author, although it includes many contributions from others.

In 1995, Guido continued his work on Python at the Corporation for
National Research Initiatives (CNRI, see http://www.cnri.reston.va.us)
in Reston, Virginia where he released several versions of the
software.
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In May 2000, Guido and the Python core development team moved to
BeOpen.com to form the BeOpen PythonLabs team.  In October of the same
year, the PythonLabs team moved to Digital Creations (now Zope
Corporation, see http://www.zope.com).  In 2001, the Python Software
Foundation (PSF, see http://www.python.org/psf/) was formed, a
non-profit organization created specifically to own Python-related
Intellectual Property.  Zope Corporation is a sponsoring member of
the PSF.

All Python releases are Open Source (see http://www.opensource.org for
the Open Source Definition).  Historically, most, but not all, Python
releases have also been GPL-compatible; the table below summarizes
the various releases.

    Release         Derived     Year        Owner       GPL-
                    from                                compatible? (1)

    0.9.0 thru 1.2              1991-1995   CWI         yes
    1.3 thru 1.5.2  1.2         1995-1999   CNRI        yes
    1.6             1.5.2       2000        CNRI        no
    2.0             1.6         2000        BeOpen.com  no
    1.6.1           1.6         2001        CNRI        yes (2)
    2.1             2.0+1.6.1   2001        PSF         no
    2.0.1           2.0+1.6.1   2001        PSF         yes
    2.1.1           2.1+2.0.1   2001        PSF         yes
    2.2             2.1.1       2001        PSF         yes
    2.1.2           2.1.1       2002        PSF         yes
    2.1.3           2.1.2       2002        PSF         yes
    2.2.1           2.2         2002        PSF         yes
    2.2.2           2.2.1       2002        PSF         yes
    2.2.3           2.2.2       2003        PSF         yes
    2.3             2.2.2       2002-2003   PSF         yes
    2.3.1           2.3         2002-2003   PSF         yes
    2.3.2           2.3.1       2002-2003   PSF         yes
    2.3.3           2.3.2       2002-2003   PSF         yes
    2.3.4           2.3.3       2004        PSF         yes
    2.3.5           2.3.4       2005        PSF         yes
    2.4             2.3         2004        PSF         yes
    2.4.1           2.4         2005        PSF         yes
    2.4.2           2.4.1       2005        PSF         yes
    2.4.3           2.4.2       2006        PSF         yes
    2.5             2.4         2006        PSF         yes
    2.7             2.6         2010        PSF         yes

Footnotes:

(1) GPL-compatible doesn't mean that we're distributing Python under
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    other software that is released under the GPL; the others don't.

(2) According to Richard Stallman, 1.6.1 is not GPL-compatible,
    because its license has a choice of law clause.  According to
    CNRI, however, Stallman's lawyer has told CNRI's lawyer that 1.6.1
    is "not incompatible" with the GPL.

Thanks to the many outside volunteers who have worked under Guido's
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direction to make these releases possible.


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Convey the object code in, or embodied in, a physical product
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library, and (2) we offer you this license, which gives you legal
permission to copy, distribute and/or modify the library.

  To protect each distributor, we want to make it very clear that
there is no warranty for the free library.  Also, if the library is
modified by someone else and passed on, the recipients should know
that what they have is not the original version, so that the original
author's reputation will not be affected by problems that might be
introduced by others.

  Finally, software patents pose a constant threat to the existence of
any free program.  We wish to make sure that a company cannot
effectively restrict the users of a free program by obtaining a
restrictive license from a patent holder.  Therefore, we insist that
any patent license obtained for a version of the library must be
consistent with the full freedom of use specified in this license.

  Most GNU software, including some libraries, is covered by the
ordinary GNU General Public License.  This license, the GNU Lesser
General Public License, applies to certain designated libraries, and
is quite different from the ordinary General Public License.  We use
this license for certain libraries in order to permit linking those
libraries into non-free programs.
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  When a program is linked with a library, whether statically or using
a shared library, the combination of the two is legally speaking a
combined work, a derivative of the original library.  The ordinary
General Public License therefore permits such linking only if the
entire combination fits its criteria of freedom.  The Lesser General
Public License permits more lax criteria for linking other code with
the library.

  We call this license the "Lesser" General Public License because it
does Less to protect the user's freedom than the ordinary General
Public License.  It also provides other free software developers Less
of an advantage over competing non-free programs.  These disadvantages
are the reason we use the ordinary General Public License for many
libraries.  However, the Lesser license provides advantages in certain
special circumstances.

  For example, on rare occasions, there may be a special need to
encourage the widest possible use of a certain library, so that it
becomes a de-facto standard.  To achieve this, non-free programs must
be allowed to use the library.  A more frequent case is that a free
library does the same job as widely used non-free libraries.  In this
case, there is little to gain by limiting the free library to free
software only, so we use the Lesser General Public License.

  In other cases, permission to use a particular library in non-free
programs enables a greater number of people to use a large body of
free software.  For example, permission to use the GNU C Library in
non-free programs enables many more people to use the whole GNU
operating system, as well as its variant, the GNU/Linux operating
system.

  Although the Lesser General Public License is Less protective of the
users' freedom, it does ensure that the user of a program that is
linked with the Library has the freedom and the wherewithal to run
that program using a modified version of the Library.

  The precise terms and conditions for copying, distribution and
modification follow.  Pay close attention to the difference between a
"work based on the library" and a "work that uses the library".  The
former contains code derived from the library, whereas the latter must
be combined with the library in order to run.


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  A "library" means a collection of software functions and/or data
prepared so as to be conveniently linked with application programs
(which use some of those functions and data) to form executables.

  The "Library", below, refers to any such software library or work
which has been distributed under these terms.  A "work based on the
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Library" means either the Library or any derivative work under
copyright law: that is to say, a work containing the Library or a
portion of it, either verbatim or with modifications and/or translated
straightforwardly into another language.  (Hereinafter, translation is
included without limitation in the term "modification".)

  "Source code" for a work means the preferred form of the work for
making modifications to it.  For a library, complete source code means
all the source code for all modules it contains, plus any associated
interface definition files, plus the scripts used to control compilation
and installation of the library.

  Activities other than copying, distribution and modification are not
covered by this License; they are outside its scope.  The act of
running a program using the Library is not restricted, and output from
such a program is covered only if its contents constitute a work based
on the Library (independent of the use of the Library in a tool for
writing it).  Whether that is true depends on what the Library does
and what the program that uses the Library does.

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fee.
   2. You may modify your copy or copies of the Library or any portion
of it, thus forming a work based on the Library, and copy and
distribute such modifications or work under the terms of Section 1
above, provided that you also meet all of these conditions:

    a) The modified work must itself be a software library.

    b) You must cause the files modified to carry prominent notices
    stating that you changed the files and the date of any change.

    c) You must cause the whole of the work to be licensed at no
    charge to all third parties under the terms of this License.

    d) If a facility in the modified Library refers to a function or a
    table of data to be supplied by an application program that uses
    the facility, other than as an argument passed when the facility
    is invoked, then you must make a good faith effort to ensure that,
    in the event an application does not supply such function or
    table, the facility still operates, and performs whatever part of
    its purpose remains meaningful.

    (For example, a function in a library to compute square roots has
    a purpose that is entirely well-defined independent of the
    application.  Therefore, Subsection 2d requires that any
    application-supplied function or table used by this function must
    be optional: if the application does not supply it, the square
    root function must still compute square roots.)
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These requirements apply to the modified work as a whole.  If
identifiable sections of that work are not derived from the Library,
and can be reasonably considered independent and separate works in
themselves, then this License, and its terms, do not apply to those
sections when you distribute them as separate works.  But when you
distribute the same sections as part of a whole which is a work based
on the Library, the distribution of the whole must be on the terms of
this License, whose permissions for other licensees extend to the
entire whole, and thus to each and every part regardless of who wrote
it.

Thus, it is not the intent of this section to claim rights or contest
your rights to work written entirely by you; rather, the intent is to
exercise the right to control the distribution of derivative or
collective works based on the Library.

In addition, mere aggregation of another work not based on the Library
with the Library (or with a work based on the Library) on a volume of
a storage or distribution medium does not bring the other work under
the scope of this License.

  3. You may opt to apply the terms of the ordinary GNU General Public
License instead of this License to a given copy of the Library.  To do
this, you must alter all the notices that refer to this License, so
that they refer to the ordinary GNU General Public License, version 2,
instead of to this License.  (If a newer version than version 2 of the
ordinary GNU General Public License has appeared, then you can specify
that version instead if you wish.)  Do not make any other change in
these notices.
   Once this change is made in a given copy, it is irreversible for
that copy, so the ordinary GNU General Public License applies to all
subsequent copies and derivative works made from that copy.

  This option is useful when you wish to copy part of the code of
the Library into a program that is not a library.

  4. You may copy and distribute the Library (or a portion or
derivative of it, under Section 2) in object code or executable form
under the terms of Sections 1 and 2 above provided that you accompany
it with the complete corresponding machine-readable source code, which
must be distributed under the terms of Sections 1 and 2 above on a
medium customarily used for software interchange.

  If distribution of object code is made by offering access to copy
from a designated place, then offering equivalent access to copy the
source code from the same place satisfies the requirement to
distribute the source code, even though third parties are not
compelled to copy the source along with the object code.

  5. A program that contains no derivative of any portion of the
Library, but is designed to work with the Library by being compiled or
linked with it, is called a "work that uses the Library".  Such a
work, in isolation, is not a derivative work of the Library, and
therefore falls outside the scope of this License.

  However, linking a "work that uses the Library" with the Library
creates an executable that is a derivative of the Library (because it
contains portions of the Library), rather than a "work that uses the
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library".  The executable is therefore covered by this License.
Section 6 states terms for distribution of such executables.

  When a "work that uses the Library" uses material from a header file
that is part of the Library, the object code for the work may be a
derivative work of the Library even though the source code is not.
Whether this is true is especially significant if the work can be
linked without the Library, or if the work is itself a library.  The
threshold for this to be true is not precisely defined by law.

  If such an object file uses only numerical parameters, data
structure layouts and accessors, and small macros and small inline
functions (ten lines or less in length), then the use of the object
file is unrestricted, regardless of whether it is legally a derivative
work.  (Executables containing this object code plus portions of the
Library will still fall under Section 6.)

  Otherwise, if the work is a derivative of the Library, you may
distribute the object code for the work under the terms of Section 6.
Any executables containing that work also fall under Section 6,
whether or not they are linked directly with the Library itself.
   6. As an exception to the Sections above, you may also combine or
link a "work that uses the Library" with the Library to produce a
work containing portions of the Library, and distribute that work
under terms of your choice, provided that the terms permit
modification of the work for the customer's own use and reverse
engineering for debugging such modifications.

  You must give prominent notice with each copy of the work that the
Library is used in it and that the Library and its use are covered by
this License.  You must supply a copy of this License.  If the work
during execution displays copyright notices, you must include the
copyright notice for the Library among them, as well as a reference
directing the user to the copy of this License.  Also, you must do one
of these things:

    a) Accompany the work with the complete corresponding
    machine-readable source code for the Library including whatever
    changes were used in the work (which must be distributed under
    Sections 1 and 2 above); and, if the work is an executable linked
    with the Library, with the complete machine-readable "work that
    uses the Library", as object code and/or source code, so that the
    user can modify the Library and then relink to produce a modified
    executable containing the modified Library.  (It is understood
    that the user who changes the contents of definitions files in the
    Library will not necessarily be able to recompile the application
    to use the modified definitions.)

    b) Use a suitable shared library mechanism for linking with the
    Library.  A suitable mechanism is one that (1) uses at run time a
    copy of the library already present on the user's computer system,
    rather than copying library functions into the executable, and (2)
    will operate properly with a modified version of the library, if
    the user installs one, as long as the modified version is
    interface-compatible with the version that the work was made with.

    c) Accompany the work with a written offer, valid for at
    least three years, to give the same user the materials
    specified in Subsection 6a, above, for a charge no more
    than the cost of performing this distribution.

    d) If distribution of the work is made by offering access to copy
    from a designated place, offer equivalent access to copy the above
    specified materials from the same place.

    e) Verify that the user has already received a copy of these
    materials or that you have already sent this user a copy.

  For an executable, the required form of the "work that uses the
Library" must include any data and utility programs needed for
reproducing the executable from it.  However, as a special exception,
the materials to be distributed need not include anything that is
normally distributed (in either source or binary form) with the major
components (compiler, kernel, and so on) of the operating system on
which the executable runs, unless that component itself accompanies
the executable.

  It may happen that this requirement contradicts the license
restrictions of other proprietary libraries that do not normally
accompany the operating system.  Such a contradiction means you cannot
use both them and the Library together in an executable that you
distribute.
   7. You may place library facilities that are a work based on the
Library side-by-side in a single library together with other library
facilities not covered by this License, and distribute such a combined
library, provided that the separate distribution of the work based on
the Library and of the other library facilities is otherwise
permitted, and provided that you do these two things:

    a) Accompany the combined library with a copy of the same work
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    facilities.  This must be distributed under the terms of the
    Sections above.

    b) Give prominent notice with the combined library of the fact
    that part of it is a work based on the Library, and explaining
    where to find the accompanying uncombined form of the same work.

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