An Overview of Sandia National Laboratory’s High Performance Computing Power Application Programming Interface (API) Specification

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Overview

- This will be a 10,000 foot view
  - The specification is necessarily broad in scope
  - Covering the specification in detail takes many hours
- A bit of history
- Collaboration from the start
- Important core principles
- Some higher level concepts
- Moving forward
Who is Behind PowerAPI?

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A UML-ish Approach

- Diagram is the result of a UML study of the target space
  - Goal: Define Scope, Roles and Interfaces
- Arrows indicate interfaces or interaction between an Actor (Role) and System
  - Each interaction represents an interface that is defined in the specification
  - Specification is structured from the user or Role perspective
- Notice that an Actor (Role) can also be a System
- Cite use case document
Goals

- Portability for the HPC community
  - Wouldn’t it be nice to develop tools that worked on all your machines with little to no modification?
  - Same desire exists no matter what Role you play
    - More about Roles later
- Forecast emerging needs of HPC community
  - As a group, inform the vendors of how we want to use systems now and in the future
    - Specification acts as a basis of collaboration
- Expose new capabilities developed by vendors and community
  - Leverage vendor and community innovations in this and related spaces
    - E.g. Geo and Redfish
- Most important, want something out there to throw stones at
  - Need a starting point!
If I had an hour to solve a problem and my life depended on it, I would use the first 55 minutes determining the proper questions to ask.

Albert Einstein
What is the Power API?

A comprehensive API for power **MEASUREMENT** and **CONTROL** of HPC platforms

- **Comprehensive** = Facility to Component
- **API** = Define the inter**FACE** not the mechanism
- **HPC platforms** = Facility (or datacenter) and all the platforms within

Considers all users of HPC platform - people and programs

- **Core (Common)**
  - Common among all “users”
    - Includes: Roles, Initialization, Navigation, Objects and Groups, Attributes (Get/Set), Metadata and Statistics

- **High-Level Common**
  - Higher level of abstraction but still potentially common among multiple Roles

- **Role/System Specific**
  - Higher level abstraction specific to how Role interfaces with system
Roles

PWR_Role

typedef enum {
    PWR_ROLE_APP, /* Application */
    PWR_ROLE_MC, /* Monitor and Control */
    PWR_ROLE_OS, /* Operating System */
    PWR_ROLE_USER, /* User */
    PWR_ROLE_RM, /* Resource Manager */
    PWR_ROLE_ADMIN, /* Administrator */
    PWR_ROLE_MGR, /* HPCS Manager */
    PWR_ROLE_ACC /* Accounting */
} PWR_Role;
Roles

- **Application** – Application or application library executing on the compute resource; May include run-time components running in user space
- **Monitor and Control** -- Cluster management or Reliability Availability and Serviceability (RAS) systems, for example.
- **Operating System** -- Linux or specialized lightweight kernels and privileged portions of run-time systems. Privilege escalation layer.
- **User** -- The end user of the HPC platform.
- **Resource Manager** – Can include work load managers, schedulers, allocators and even portions of run-time systems that manage resources.
- **Administrator** – System administrator or day-to-day platform manager.
- **HPCS Manager** -- Individual(s) responsible for managing policy for the HPC platform, often through scheduling policy. Implements facility parameters.
- **Accounting** -- Individual or software that produces reports of metrics for the HPC platform.
System Description

Presents a navigable view of the system’s hardware components (objects) upon initialization
- Can extend to custom object types
- Can be heterogeneous

```
typedef enum {
    PWR_OBJ_PLATFORM = 0,
    PWR_OBJ_CABINET,
    PWR_OBJ_CHASSIS,
    PWR_OBJ_BOARD,
    PWR_OBJ_NODE,
    PWR_OBJ_SOCKET,
    PWR_OBJ_CORE,
    PWR_OBJ_POWER_PLANE,
    PWR_OBJ_MEM,
    PWR_OBJ_NIC,
    PWR_NUM_OBJ_TYPES,
    /* */
    PWR_OBJ_INVALID = -1,
    PWR_OBJ_NOT_SPECIFIED = -2
} PWR_ObjType;
```
Objects

- Objects and Groups
  - Objects represent components of a system
    - Lots of flexibility in what a component is
  - System Description is the organization of these objects to represent the system
  - Representation may be dependent on Role (and other considerations)
  - Attributes (later) are associated with objects
  - Groups can be implementation (predefined) or user defined (long or short lived)

- Navigate the system description provided upon Initialization
  - Entry point may depend on Role
    - Node entry point for Application
    - Platform entry point for Administrator
  - Navigate up (parent object), down (child objects)
  - Navigation can also be thought of as Discovery
typedef enum {
    PWR_ATTR_PSTATE = 0, /* uint64_t */
    PWR_ATTR_CSTATE, /* uint64_t */
    PWR_ATTR_CSTATE_LIMIT, /* uint64_t */
    PWR_ATTR_SSTATE, /* uint64_t */
    PWR_ATTR_CURRENT, /* double, amps */
    PWR_ATTR_VOLTAGE, /* double, volts */
    PWR_ATTR_POWER, /* double, watts */
    PWR_ATTR_POWER_LIMIT_MIN, /* double, watts */
    PWR_ATTR_POWER_LIMIT_MAX, /* double, watts */
    PWR_ATTR_FREQ, /* double, Hz */
    PWR_ATTR_FREQ_LIMIT_MIN, /* double, Hz */
    PWR_ATTR_FREQ_LIMIT_MAX, /* double, Hz */
    PWR_ATTR_ENERGY, /* double, joules */
    PWR_ATTR_TEMP, /* double, degrees Celsius */
    PWR_ATTR_OS_ID, /* uint64_t */
    PWR_ATTR_THROTTLLED_TIME, /* uint64_t */
    PWR_ATTR_THROTTLLED_COUNT, /* uint64_t */
    PWR_NUM_ATTR_NAME,
    /* */
    PWR_ATTR_INVALID = -1,
    PWR_ATTR_NOT_SPECIFIED = -2
} PWR_AttrName;
Attribute Interface

MEASURE

```c
int PWR_ObjAttrGetValue( PWR_Obj object,
                        PWR_AttrName attr,
                        void* buf,
                        PWR_Time* ts);
```

CONTROL

```c
int PWR_ObjAttrSetValue( PWR_Obj object,
                         PWR_AttrName attr,
                         void* buf );
```

Symmetric calls available for operating on groups of objects
Attributes: Common Functionality

- **Attributes** (measure and control) of objects and groups of objects
  - Access dependent on Role and other implementation specific considerations

- **Get and Set operations** enable basic measurement and control for the exposed object attributes (and groups of objects)

- Attributes can represent generic measurement and control features
  - Power, Voltage, Current, Frequency

- Architecture specific features are permissible at the lowest levels
  - Pstate, Cstate may not be meaningful for all architectures

- An attribute, like power, can represent an instrumentation point or a summation of underlying instrumentation points
  - Power attribute of a CPU object
  - Power attribute of a Node object
typedef enum {
    PWR_MD_NUM = 0, /* uint64_t */
    PWR_MD_MIN, /* either uint64_t or double, depending on attribute type */
    PWR_MD_MAX, /* either uint64_t or double, depending on attribute type */
    PWR_MD_PRECISION, /* uint64_t */
    PWR_MD_ACCURACY, /* double */
    PWR_MD_UPDATE_RATE, /* double */
    PWR_MD_SAMPLE_RATE, /* double */
    PWR_MD_TIME_WINDOW, /* PWR_Time */
    PWR_MD_TS_LATENCY, /* PWR_Time */
    PWR_MD_TS_ACCURACY, /* PWR_Time */
    PWR_MD_MAX_LEN, /* uint64_t, max strlen of any returned metadata string. */
    PWR_MD_NAME_LEN, /* uint64_t, max strlen of PWR_MD_NAME */
    PWR_MD_NAME, /* char *, C-style NULL-terminated ASCII string */
    PWR_MD_DESC_LEN, /* uint64_t, max strlen of PWR_MD_DESC */
    PWR_MD_DESC, /* char *, C-style NULL-terminated ASCII string */
    PWR_MD_VALUE_LEN, /* uint64_t, max strlen returned by PWR_MetaValueAtIndex */
    PWR_MD_VENDOR_INFO_LEN, /* uint64_t, max strlen of PWR_MD_VENDOR_INFO */
    PWR_MD_VENDOR_INFO, /* char *, C-style NULL-terminated ASCII string */
    PWR_MD_MEASURE_METHOD, /* uint64_t, 0/1 depending on real/model measurement */
    PWR_NUM_META_NAMES,
    /* */
    PWR_MD_INVALID = -1,
    PWR_MD_NOT_SPECIFIED = -2
} PWR_MetaData;
Metadata: Common Functionality

- **Metadata** interface provides information about quality, frequency, and other characteristics associated with attributes of objects
  - Can be specific for a particular attribute/object pair
    - All power sensors might not provide the same accuracy
  - Frequency of sample collection can help determine usefulness of data
  - Can also, in some cases, set metadata
    - Potentially to change how a device responds
Statistics Interface

PWR_AttrStat

typedef enum {
    PWR_ATTR_STAT_MIN = 0,
    PWR_ATTR_STAT_MAX,
    PWR_ATTR_STAT_AVG,
    PWR_ATTR_STAT_STDEV,
    PWR_ATTR_STAT_CV,
    PWR_NUM_ATTR_STATS,
    /* */
    PWR_ATTR_STAT_INVALID = -1,
    PWR_ATTR_STAT_NOT_SPECIFIED = -2
} PWR_AttrStat;
Statistics: Common Functionality

- **Statistics** interface gathers data on one or more attributes for an object or group of objects
  - Real time or historic statistics
    - Historic implies data retention (database for example)
  - Min, Max, Average, Standard Deviation, Coefficient of Variation
  - Reduction operation available
  - User provided statistic function on the to-do list

- Provides functions to...
  - Start, stop, and reset statistics gathering
  - Get the calculated value(s) for the object or group of objects
  - Reduce the values calculated for objects in a group into a single value
High Level Interfaces by Role (1)

Administrator:
- Apply Hard Power Limits based on Facility parameters
  - Bounds Power Aware Scheduling

Accounting:
- Power/Energy Application profiling based on historic information
  - Feeds into Power Aware Scheduling
High Level Interfaces by Role (2)

Resource Manager
- Power Aware Scheduling
  - HPC Tetris

User
- Understands application Power and Energy Characteristics and Phases

Application
- Provide application hints based on profiling
One Implementation Across Multiple Interfaces

Decision based on what ROLE is asking

Single API Implementation

Decision based on where data exists

Monitor and Control

Resource Mgr

Database

Acct Mgr

Administrator

User
Reference Implementation

Available online and open source: [http://github.com/pwrapi](http://github.com/pwrapi)
Power API Timeline

- 2013: Use case document prepared by SNL and NREL and reviewed by partners
- July 2014: Draft specification review meeting with cross-vendor panel of experts
- Sept. 2014: Day-long community launch meeting with labs, industry, academia
- Jan. 2015: Prototype implementation release
- Aug. 2015: Specification v1.1 release
81 Countries as of October 2015
Trinity ATS-1 NRE: Advanced Power Management

- DOE NNSA’s Advanced Technology System (ATS-1)
  - >19,000 Nodes, <10MW
- Introduced the concept of funding Non-Recurring Engineering (NRE) projects to advance important technologies in conjunction with platform procurement
- Cray contracted to address Advanced Power Management
  - Implement portions of the Power API at scale

Targeting two areas of the API:

1. Implement interface to Power Management Database
   - Extend specification to include Python
   - Monitor and Control in our diagram
2. Compute node implementation (native C)
Going Forward

- How do we move forward?
- What “standards” model to apply?
- Regular calls?
  - Frequency?
- Face to Face meetings
  - Frequency?
- Important to have broad community participation which includes vendor representatives
Thank you – Questions?

http://powerapi.sandia.gov/

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