State of the Practice: Energy and Power Aware Job Scheduling and Resource Management (EPA-JSRM)

EEHPC Working Group
EPA-JSRM sub-team

November 15, 2017
SC’17, Denver CO
Focus of this BoF:
State of the Practice: Energy and Power Aware Job Scheduling and Resource Management (EPA-JSRM)

Background of the EPA-JSRM team:
• Sub-team under the Energy Efficient HPC Working Group
• Includes interested members from across the globe
  • HPC Centers/Facilities
  • Researchers
  • Vendors
• Goal: Assess the environmental, computational, and usage drivers motivating power management efforts

Recent work:
• Identify the State of Practice regarding EPA-JSRM
• Survey done in 2016/2017
• White-paper + poster published

Today’s Agenda
• Summarize key takeaways from the white paper
• Get feedback from the audience on the next steps and future roadmaps.
System Design Challenges:

- Peak power demands for future Exascale systems ~20-30MW
- Microarchitecture improvements and high degree of parallelization not sufficient

Resource Management Approaches

Operation of the plant that houses the supercomputer system

Operation of the supercomputer system

Tools and Capabilities

- Facility Resources
- HPC Resources
- Application Profiling and Scheduling

Energy Efficiency Strategies

System Power Capacity
- Power Fluctuations
- Peak Power
- Application Efficiency
- Optimization
- HW Architecture Capability

Scope of the survey and this BOF!
First global survey of EPA-JSRM capabilities among supercomputing sites

Participating Sites:

• **CEA** (Alternative Energies and Atomic Energy Commission), France
• **CINECA**, Italy
• **JCAHPC** (University of Tsukuba, University of Tokyo), Japan
• **KAUST** (King Abdullah University of Science and Technology), Saudi Arabia
• **LRZ** (Leibniz Supercomputing Centre), Germany
• **RIKEN**, Japan
• **STFC** (Science and Technology Facilities Council), United Kingdom
• **Tokyo Institute of Technology**, Japan
• **Trinity** (Los Alamos and Sandia National Laboratories), United States

Criteria for inclusion in the survey:

• Be **actively pursuing** an EPA-JSRM solution, and
• Targeting solution on a **large-scale HPC system**, and
• Be investing in technology development with the intention of using the EPA-JSRM solution in the site’s production computing environment.
Survey Responses to be discussed today...
• Motivation for investing in EPA-JSRM solutions
• Adopted design and implementation details
• Results and challenges
• Next steps

Remaining questions addressed in more detail in the white paper:
• Target infrastructure & workload characteristics/
• https://eehpcwg.llnl.gov/pages/conf_sc17a.htm
Motivation for investing in JSRM solutions

• Power constraints due to external factors
  • Natural disasters, shortage of electricity
  • Government mandates, limits to operation costs

• Power limits imposed due to internal infrastructure limitations

• Motivation for staying "ahead of the game" while dealing with power constraints
  • Investments in predictability and stability of power consumptions of future systems

• Prioritization of higher compute power by limiting secondary infrastructure costs like cooling, etc.

• Education and evaluation of end users

• Ecological responsibility: desire to "be green"
EPA-JSRM design overview

System-wide monitoring and control agents in a traditional HPC system

Resources in a traditional HPC system
Measurement and Modeling solutions

• Sensors for monitoring energy and power
  • Both in-band as well as out-of-band
  • Direct real-time measurements

• Thermal-based sensors coupled with prediction models
# EPA-JSRM Solutions Adopted

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<tr>
<th>#</th>
<th>Approach</th>
<th>Challenges</th>
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<td>A.</td>
<td>Dynamic termination of jobs</td>
<td>• Choosing the right metric for terminating jobs</td>
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<td>• Job selection based on job size, job length, etc. to shut down</td>
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<td></td>
<td>• RIKEN</td>
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<td>B.</td>
<td>Automated reduction of node availability</td>
<td>• Drop in system availability</td>
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<td>• Reduces the theoretical maximum power that can be consumed</td>
<td>• Already shut-down nodes take time to boot up. This increases queue wait-time for jobs that are waiting for those nodes.</td>
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<td>• Resource manager and job scheduler play an important role</td>
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<td></td>
<td>• Tokyo Tech</td>
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<td>C.</td>
<td>Use of power-capping mechanisms</td>
<td>• Out of band / SLURM SDPM: High performance variability in performance has been observed low queue wait times, coarse grained power limiting.</td>
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<td>• Attempts to keep total power consumed below a specific limit.</td>
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<td>• Power cap applied over a specific time-window, e.g. Intel RAPL</td>
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<td>• SLURM – SDPM, Cray’s CAPMC</td>
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<td></td>
<td>• KAUST, Tokyo Tech, JCAHPC, Cineca</td>
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<td>D.</td>
<td>Leveraging p-states (for specific jobs); c-states + s-states (for idle nodes)</td>
<td>• Design of standardized user interfaces / portable APIs</td>
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<td>• SLURM, IBM Load Leveler -- Platform LSF</td>
<td>• Granularity of p-state change – per process v/s job</td>
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<td>• CEA, LRZ, STFC</td>
<td>• Platform specific</td>
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<td>E.</td>
<td>Static prediction models</td>
<td>• Selection of input parameters for the static model</td>
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<td>• System-wide control</td>
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<td></td>
<td>• Implemented within job schedulers, and used history of past runs</td>
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<td>• IBM Load leveler</td>
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<td>• LRZ, STFC</td>
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<td>F.</td>
<td>Tagging applications based on power characteristics</td>
<td>• Dependent on user input</td>
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<td>• Mapping of “tags” to performance metrics</td>
<td>• Need to maintain historical records</td>
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<td>• Tag-values for future budget assignment</td>
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<td>• LRZ, STFC</td>
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Short and Long Term Goals

- To be used in procurement documents
- Strong interest in continuing development and deployment

Long term goals
- Implement power estimator for the jobs
- Invest in extending power capping mechanisms to multiple systems within the same site
- Incorporate facility power and cooling information within the JSRM solution
Next Steps...

<table>
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<tr>
<th>For sites</th>
<th>For vendors</th>
<th>For the community</th>
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<td>• What granularity do you see your site adopting EPA-JSRM solutions – job, node, socket, core, memory, network?</td>
<td>• (Schedulers)</td>
<td>• Standardization of Interfaces across components</td>
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<td>• What opportunity analysis data is needed to encourage adoption of fine-grained control?</td>
<td>• Interfaces for collecting power/energy constraints from users / sys admins</td>
<td>• Need for additional surveys</td>
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<td>• Topology-aware placement</td>
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<td>• (OS) Kernel modules for controlling power/ energy</td>
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<td>• (System components)</td>
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<td>• Interfaces for setting/reading power/energy control knobs, MSRs, CSRs</td>
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## Next Steps...
*(input from audience)*

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| • What granularity do you see your site adopting EPA-JSRM solutions – job, node, socket, core, memory, network?  
  -- Expose user priority (account for turnaround time)  
  -- incentive for users (e.g. CPU allocation time, tied that with power mgmt solutions, constrained resource)  
  -- shortlist metrics | • (Schedulers)  
  • Interfaces for collecting power/energy constraints from users / sys admins  
  • Topology-aware placement  
  -- relying on user-input -- skepticism  
  -- machine learning, data analytics  
  -- topology awareness: expose topology in some format, n/w related placement (performance --> energy efficiency), balancing nodes (monitoring interfaces) | • Standardization of Interfaces across components |
| • What opportunity analysis data is needed to encourage adoption of fine-grained control?  
  --> LRZ has research, not deployment ready  
  --> KAUST: two job queues (high/low limit), design different versions of the same code -- user's responsibility, instrumenting codes  
  --> CRAY: profiling tools (e.g. craypat, perftools)  
  --> STFC: visuals for load imbalance  
  ORNL's challenges:  
  -- reliability of profiling tools?  
  -- tools: prefer tools delivered by vendors  
  DOD: main concern:  
  Total cost of ownership, operation costs  
  7:1 = (operation costs: energy costs) | • (OS) Kernel modules for controlling power/ energy | • Need for additional surveys  
  • (System components)  
  • Interfaces for setting/ reading power/energy control knobs, MSRs, CSRs |
Closing thoughts...

• Do get in touch if you would like to participate!

• **Contact Info:**
  - Natalie Bates
    - natalie.jean.bates@gmail.com
  - Subscribe to EPA-JSRM mailing list:
    - Google group: epa-jsrm@googlegroups.com