UT-BATTELLE

Dynamic Self-Aware Runtime Software for Exascale Systems

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C. Engelmann, G. Vallée, T. Naughton, and F. Mueller. Dynamic Self-Aware Runtime Software for Exascale Systems. Oct. 4-5, 2012.

Why Do wee Need A Dynamic Self-Aware Runtime Software for Exascale Systems?

Background and motivation

- Power consumption is a major component of operating costs (1MW/year = $1,000,000/year)
- With lower component reliability and higher component counts faults will occur frequently
- At 1 billion cores, even a tiny amount of load imbalance can severely affect performance
- System power consumption, resilience, and performance properties change dynamically
- Application performance and resilience needs change as well

Objective

- Offer awareness about system properties and application needs
- Provide autonomous adaptation to dynamically changing system properties and application needs
- Optimize power consumption, resilience, and performance

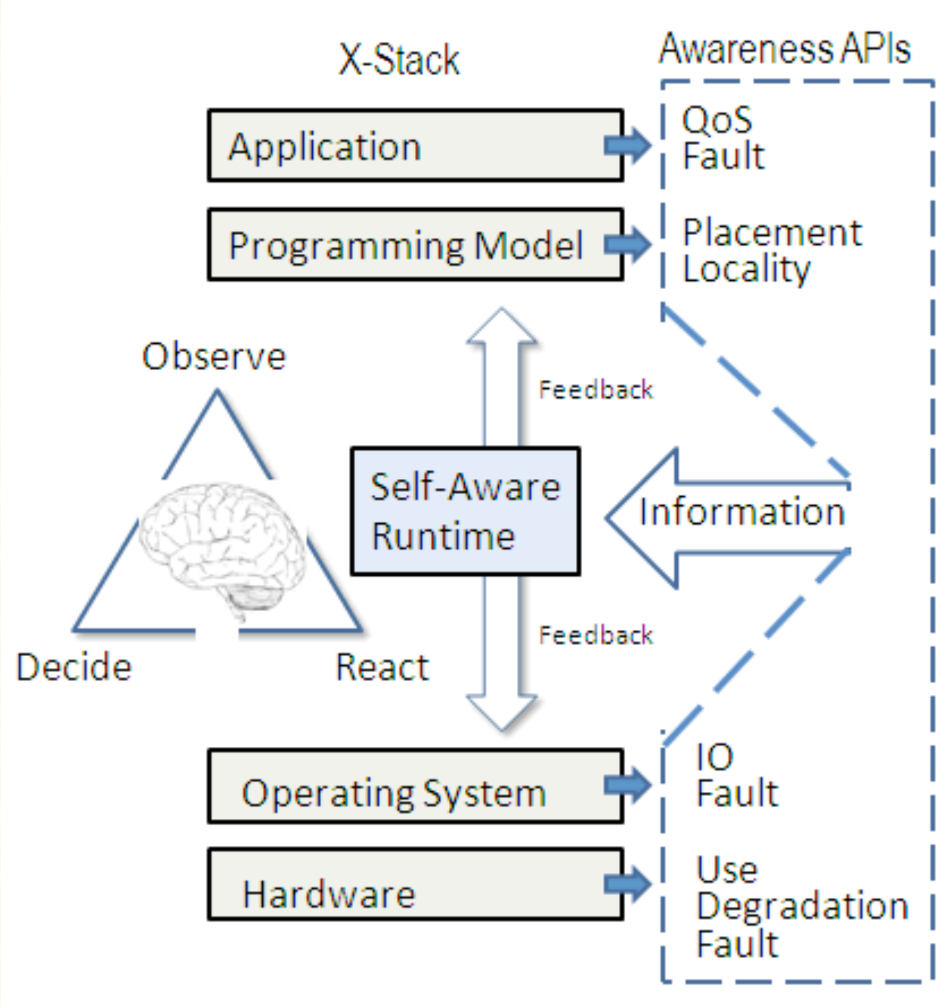
Preliminary accomplishments

- Energy-aware job scheduling
- Energy-aware computing using and voltage/frequency scaling
- Proactive fault tolerance using process migration
- Load balancing via process migration or data repartitioning

A Dynamic Self-Aware Runtime for Energy Efficiency, Resilience, and Performance

Proposed concept

- **A runtime that is aware of dynamic changes and able to autonomously respond**
- **Employs a control loop with system monitoring (observe), decision models (decide), and corrective actions (react)**
- **Awareness APIs offer a holistic view of the current system state**
- **A controller processes the system state and application QoS requests using models**
- **Feedback interfaces enable corrective actions**



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Proposed Research In A Dynamic Self-Aware Runtime for Exascale Systems

System monitoring:

- ***Load/Power awareness:***
  - Core/node utilization
- ***Reliability awareness:***
  - Early failure indications
  - Core/node temperatures
- ***Progress awareness:***
  - Comm. patterns/wait times
  - Application epochs

Decision models:

- Energy-, load-, and progress-aware power management
- Load-, progress-, and reliability-aware scheduling and migration
- Single and across-node models
- Feedback/feed-forward control

Corrective actions:

- Power management
- Task scheduling
- Process pinning and migration

Self-aware runtime framework:

- Monitoring via OS, IPMI, SMART
- Data dissemination using Gossip
- Event-based framework using out-of-band and/or piggybacking
- Integrated with vendor RAS system, OS, programming runtime, and application

Targeted Dynamic Optimization for Energy Efficiency, Resilience, and Performance

Task scheduling to improve:

- ***<u>Energy efficiency</u>*** **and** ***<u>load balance</u>*** **by matching system resources with application needs**

Single-node power management to improve a node's:

- ***<u>Energy efficiency</u>*** **by slowing down underutilized cores**
- ***<u>Load balance</u>*** **by slowing down cores that are ahead and speeding up those behind**

Single-node process pinning and migration to improve a node's:

- ***<u>Reliability</u>*** **by wear-leveling cores**
- ***<u>Reliability</u>*** **by distributing heat**

Across-node power management to improve a system's:

- ***<u>Energy efficiency</u>*** **by slowing down all cores**

Across-node process migration to improve a system's:

- ***<u>Load balance</u>*** **by moving processes from over- to underutilized nodes**
- ***<u>Reliability</u>*** **by wear-leveling node usage**
- ***<u>Reliability</u>*** **by distributing hot spots across nodes**
- ***<u>Reliability</u>*** **by anticipating imminent node failures (proactive fault tolerance)**