A Runtime Environment for Supporting Research in Resilient HPC System Software & Tools

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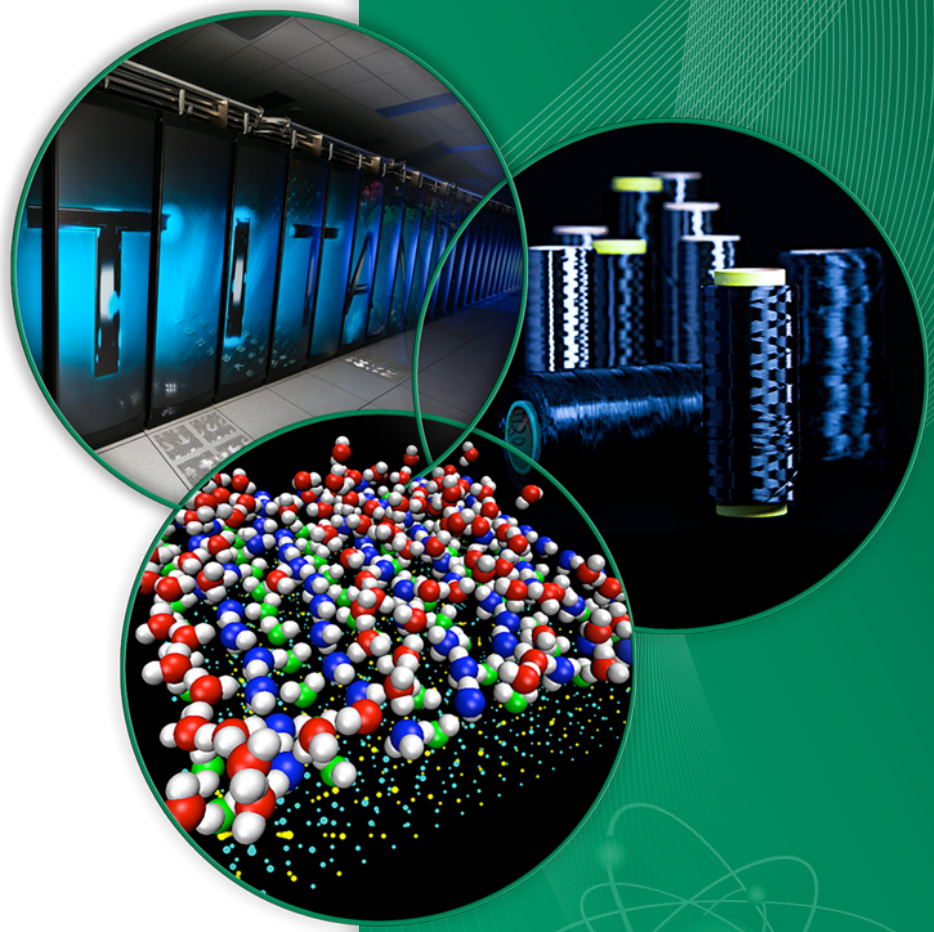


Motivation & Challenges

- High performance computing trends
  - Bigger machines (e.g., TITAN, upcoming exascale systems)
  - More complex architectures (e.g., heterogeneous compute nodes)
  - More failures
- Runtime environment (RTE) is a crucial software component
  - Interface between the operating system and scientific simulation
  - Manage the lifecycle of the scientific simulation

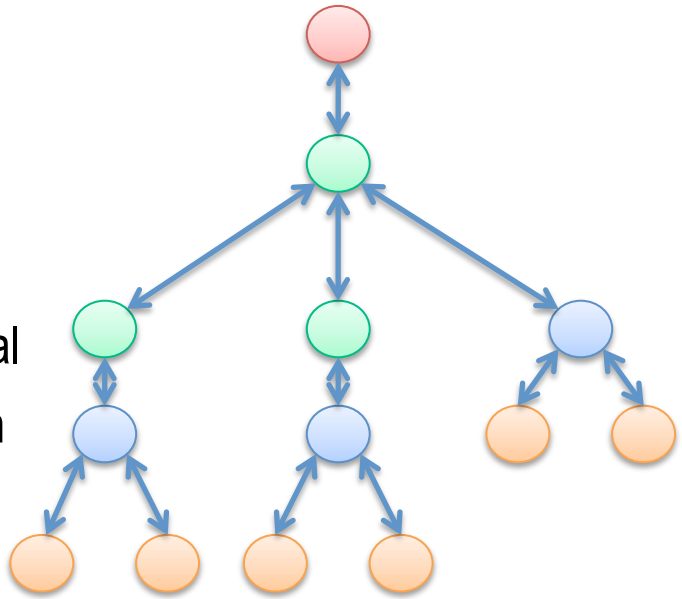
Is it possible to provide building blocks for the study and development of new RTEs?

Scalable RunTime Component Infrastructure – STCI

- Goals
  - Scalable start-up and management of scientific simulations
  - Resilience/fault tolerance
  - Ease the study and development of new system tools and/or applications for HPC
- Key characteristics
  - Modular architecture
  - Provide reusable components
- Illustration with 2 use cases
  - Alternate MPI runtime
  - New fault injection tool

STCI Architecture

- Agents
  - Instantiate both the STCI infrastructure and applications/tools
  - Different “types” of agents
    - *Frontend*: user frontend running on user’s terminal
    - *Controller*: logical agent representing the job from a control point of view
    - *Root agent*: privileged agent for resource allocation; one per node; non-specific to a job
    - *Session agent*: local management of users’ job; one per user and per node
    - *Tool agent*: instantiation of an application or a tool
- Topologies
  - Represent connections between agents
  - Examples: trees, meshes, binomial graphs



STCI Architecture (2)

- Launcher
  - Deploy a job by creating the necessary agents across the HPC platform
  - Two challenges
    - Scalable deployment method: by default, a tree-based topology
    - Method to create the required agents
      - Example: fork, ssh, ALPS
      - On Cray:
        - » Torque gives the list of target compute nodes
        - » ALPS is used to create the RAs
        - » then RAs create other agents
- Event system
  - Support for asynchronous execution model
  - Various progress models available: implicit or explicit progress

STCI Architecture (3)

- Two communication substrates
  - One dedicated to bootstrapping
  - One for the implementations of parallel/distributed services
- Bootstrapping communication substrate
  - Requirements
    - Self-bootstrapping
    - Reliable and ordered communications
    - Support sparse connectivity
    - Support fine-grain monitoring of all communication links (agents may be volatile)
    - Support asynchronous communications
  - Currently based on a tree topology

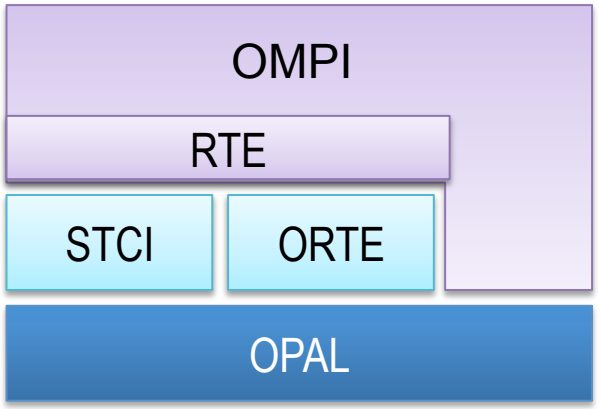
STCI Architecture (4)

- Active Message (AM) communication substrate
  - Requirements
    - Reliable communications
    - Blocking/non-blocking send
    - Avoid data copies
    - Sparse connectivity
    - Asynchronous communications
  - 3 different AM APIs with different levels of abstraction
    1. Point-to-point, non-routed fragment-based communications
    2. Point-to-point, routed message-based communications
    3. Stream based (based on a topology), routed message-based communications

STCI Architecture (5)

- Fault tolerance
  - Failure detection
    - Inter-node: e.g., mesh topology between compute nodes
    - Intra-node: e.g., signal based detector
  - Fault tolerant topology
    - Topology that tolerates the failure of one or more agent
    - Ex: binomial graph (BMG) based topology providing redundant communication links
  - Failure notification
    - Propagate any local notification from detectors
    - Abstract how the propagation is implemented (ex: broadcast notification, tree-based fan-in/fan-out)
  - Error manager
    - Implement the consensus policy for failure recovery (ex: terminate on failure)
    - Local and global recovery managers

Use Case – Alternate Runtime for MPI



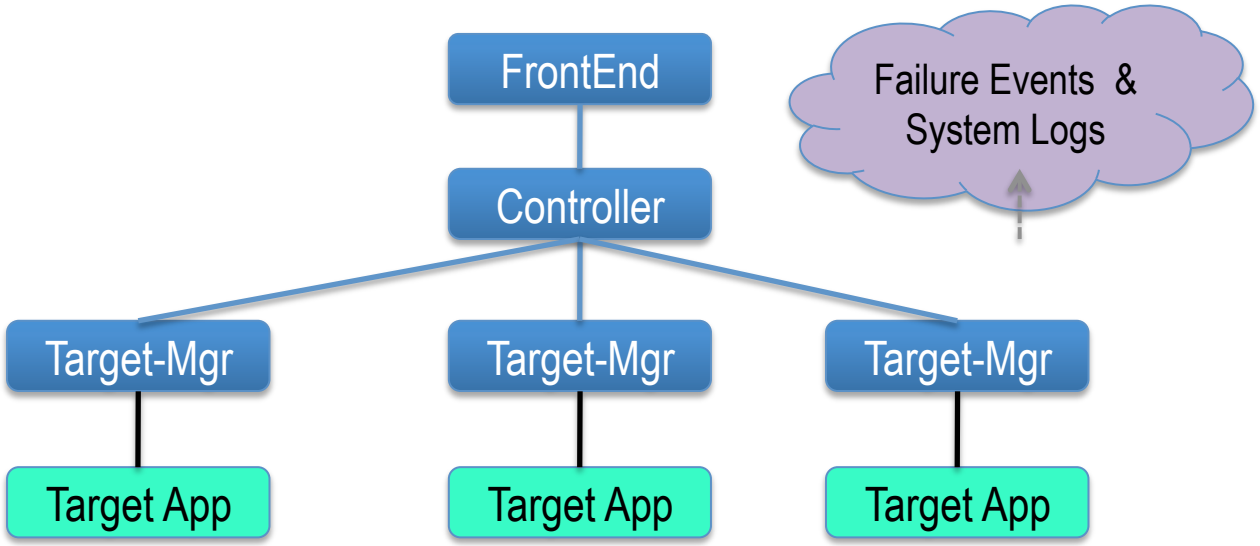
- Based on Open-MPI
  - Replace the default runtime (ORTE)
  - Benefit the RTE abstraction in Open-MPI
    - Out-of-band communications
    - Naming service
  - RTE mainly used for the deployment of MPI ranks
    - STCI communication substrates used during bootstrapping
    - Open-MPI high-performance communication substrates once bootstrapping completed
- Used for the implementation of the fault tolerant MPI prototype
  - Ongoing MPI-3.x standardization
  - Focusing on user-level failure mitigation (ULFM)

Use Case – Fault Injection Tool

- Goal
  - Study the impact of faults
  - Validate mitigation mechanisms
- Development of a new tool
  - Specialized frontend and distributed control
  - Experiment setup/management
  - Monitoring and event logging
  - Fault injection mechanisms, e.g., process kill for process fail-stop

Use Case – Fault Injection Tool (2)

- Users provide a description of the experiment via the frontend
- Session agents implement the target manager, which will apply a fault injection mechanism on the target application



Conclusion

- STCI provides a modular architecture that
  - Tolerates failures at the infrastructure level
    - give users the opportunity to be notified
    - Let users decide the appropriate actions
  - Minimizes the bootstrapping phase during which the entire infrastructure is at risk
  - Eases the design and implementation of HPC tools
  - Provides all the building blocks for supporting research in resilience
- Used at ORNL to enable research related to resilience
  - MPI Fault tolerance Working group – ULFM
  - Resilience tool for HPC via fault injection

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