Characterizing the Performance of Executing Many-tasks on Summit

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Outline

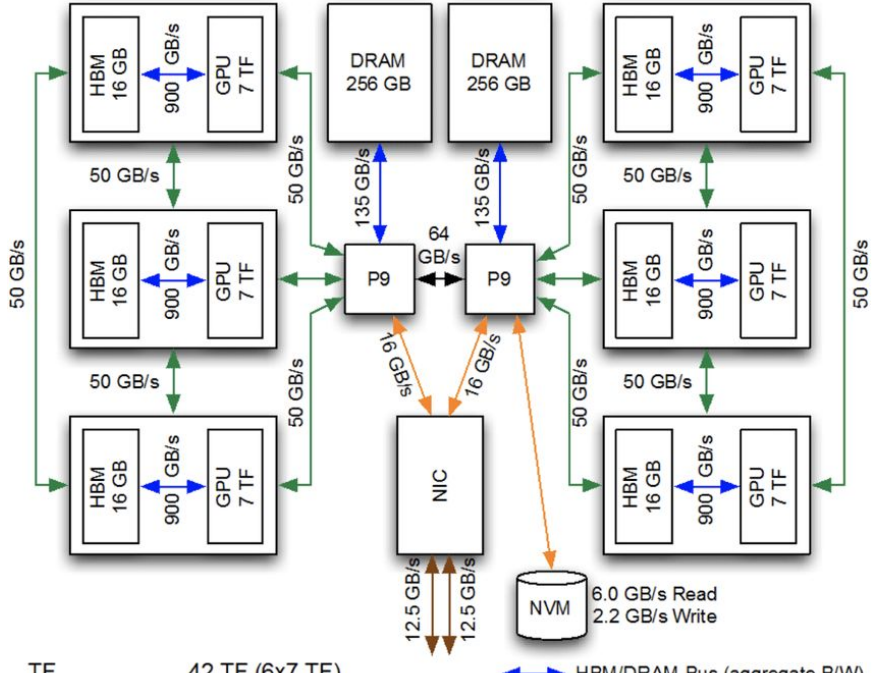
- Many-tasks applications on high performance computing platforms
- Summit architecture
- Implementing the pilot abstraction on Summit
- Performance comparison between JSM and PRRTE-based implementations
- Overheads decomposition and performance improvement

Many-tasks Applications on HPC

- Workloads of many scientific applications are comprised of many tasks: molecular dynamics, seismology, climate sciences, particle physics, etc.
- Tasks are independent, self contained computing unit, i.e., executables
- Tasks can be heterogeneous: type/amount of resources and execution time
- Requires HPC platforms for both scale and performance
- Adoption of HPC platforms presents many challenges:
  - Departing from traditional paradigms: single, large MPI executable
  - Acquisition and dynamic management of heterogeneous resources
  - Coping with resource policies designed for traditional HPC use cases

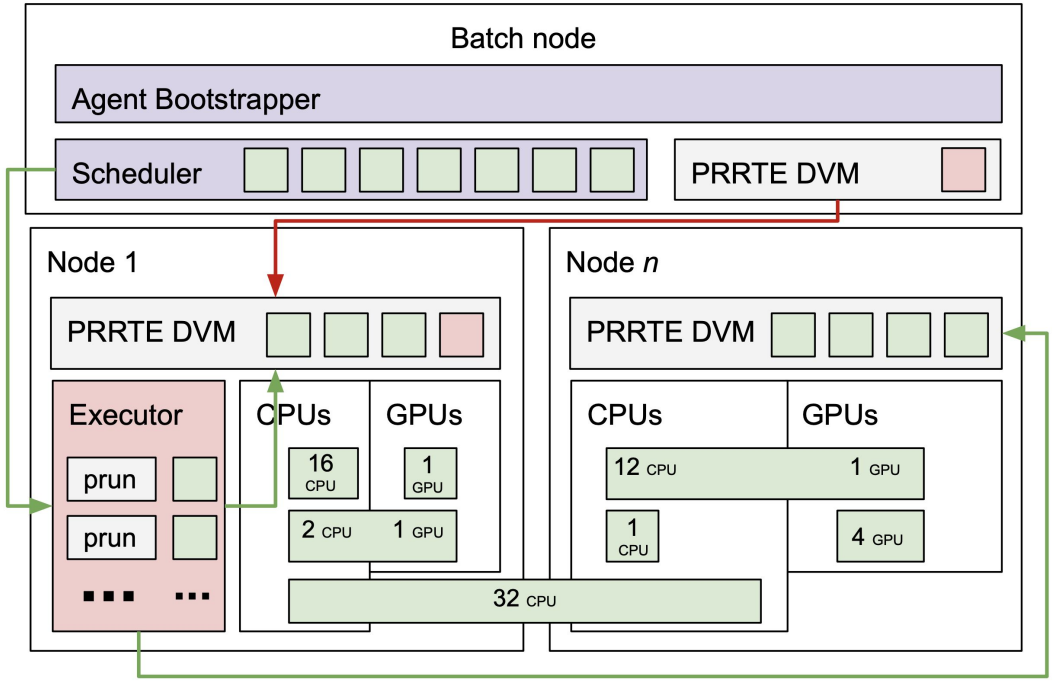
Summit at Oak Ridge National Lab

- 4,600 compute nodes IBM Power System AC922
- Each node:
  - 2 IBM POWER9 22C 3.07GHz, each supporting 4 HW threads
  - 6 NVIDIA Volta GV100
  - 512 GB of DDR4 for POWER9 and 96 GB of High Bandwidth Memory (HBM2) for GPU



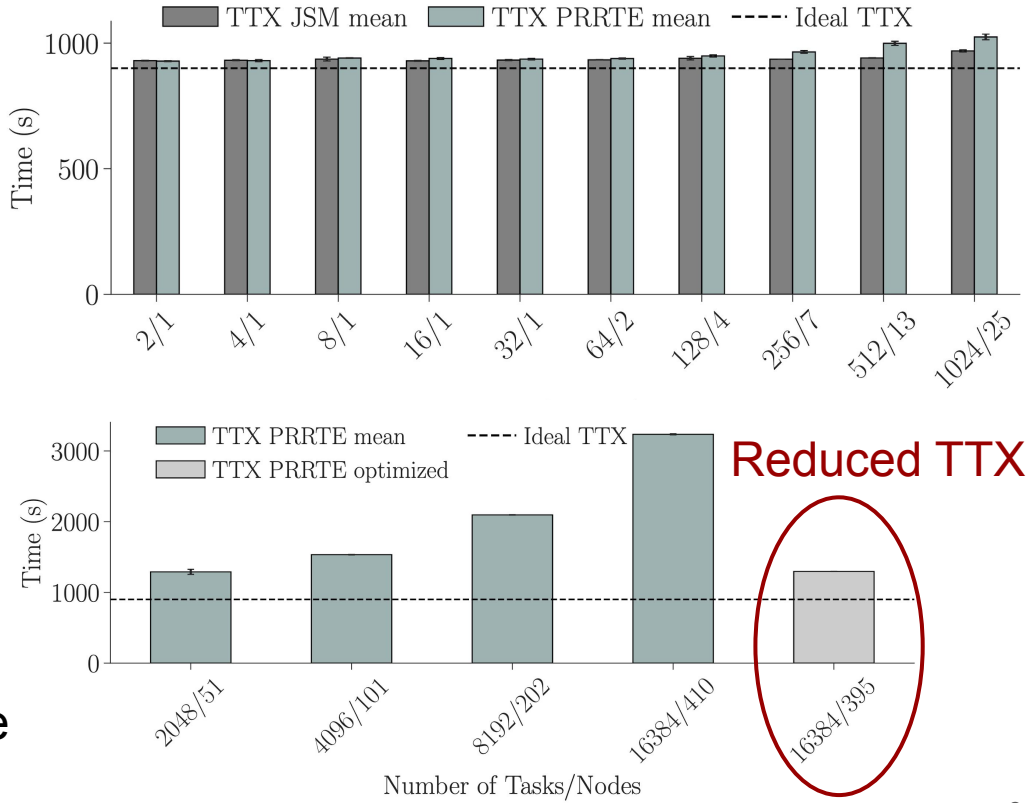
Implementing the Pilot Abstraction on Summit

- Pilot: scheduling, placing and launching tasks on job resources
- BM Job Step Manager (JSM)
- Process Management Interface for Exascale (PMIx)
- PMIx Reference RunTime Environment (PRRTE)
- RADICAL-Pilot (RP)
- Integration of: RP+PRRTE and RP+JSM



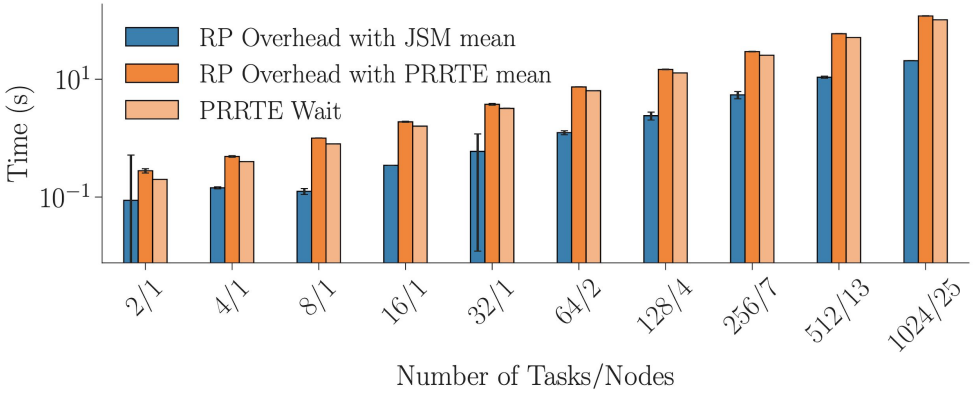
Performance comparison: Total Execution Time (TTX)

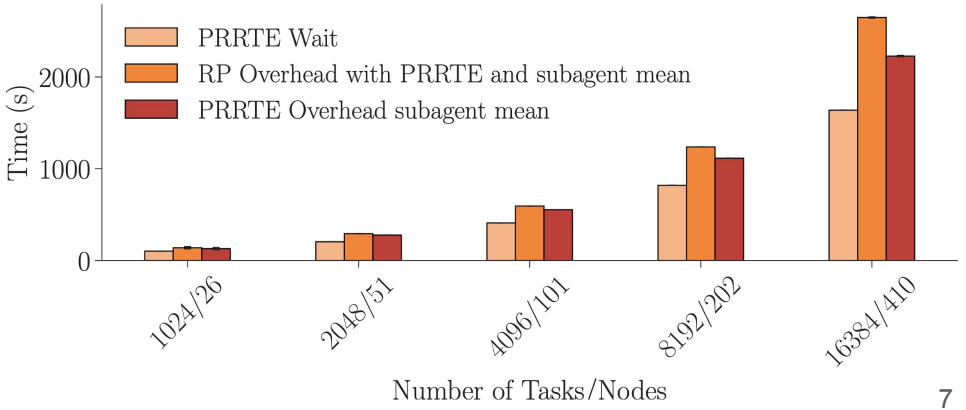
- Global performance view of TTX with RP+JSM and RP+PRRTE
- Many-tasks application:
  - 2-16384, 1 core, 15m, tasks
  - 1-410 Summit work nodes
  - Worse case scenario
- Scaling of JSM: 1024 tasks
- Scaling of PRRTE: ~20K tasks
- RP+PRRTE TTX slightly higher than PR+JSM TTX
- RP+PRRTE TTX exponential due to RP implementation (reduced)



Performance comparison: TTX Decomposition

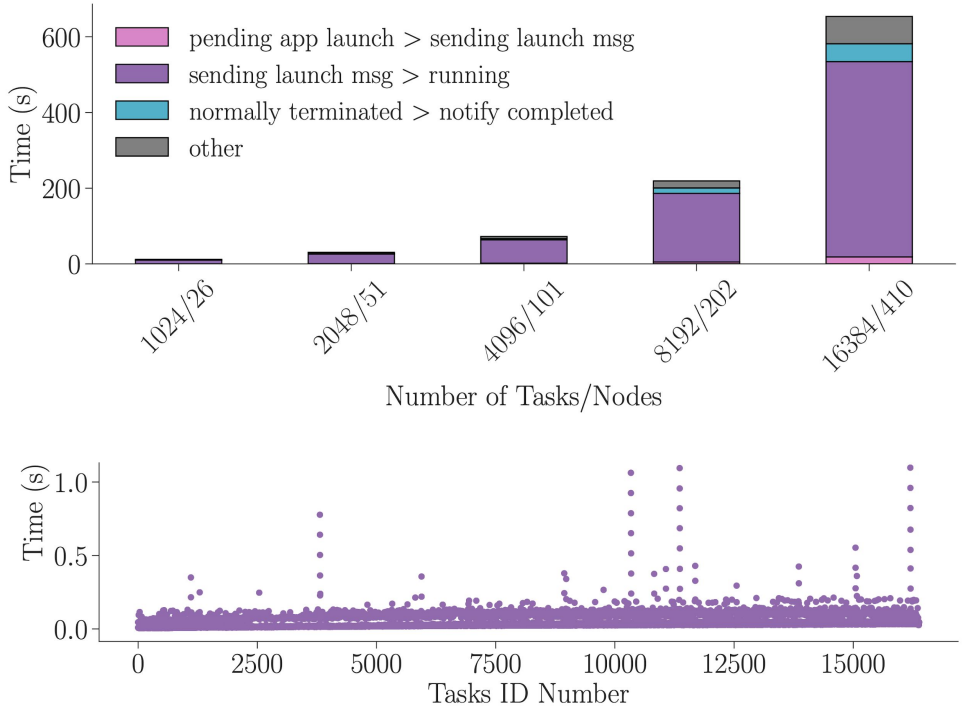
- Overhead view of TTX with RP+JSM and RP+PRRTE
- RP+JSM overhead:
  - Higher variance than RP+PRRTE
  - Lower mean than RP+PRRTE
- RP+PRRTE overhead:
  - Almost no variance
  - Scales ~linearly
  - Mostly due to RP wait time
- Without RP wait time, PRRTE overhead is negligible compared to other overheads.



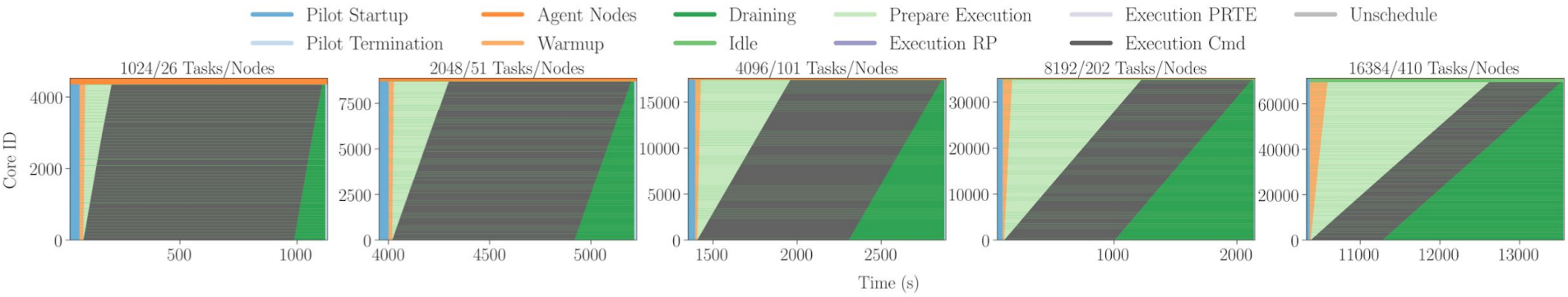


Decomposition of PRRTE Execution Time

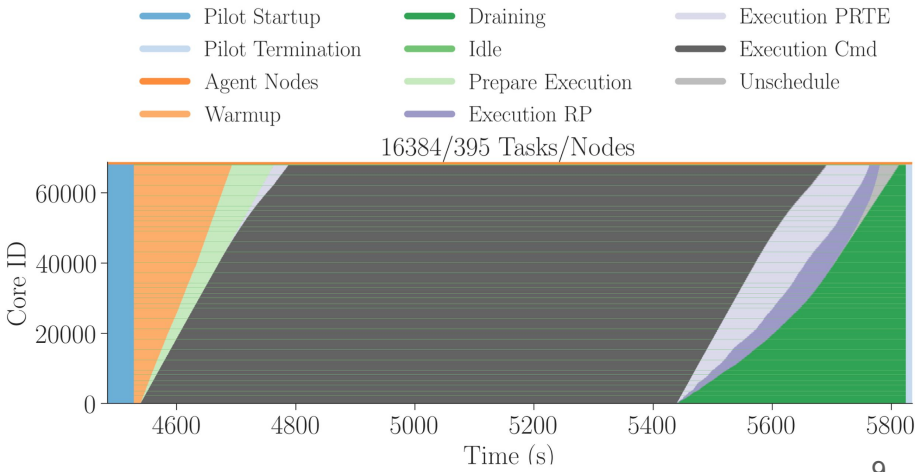
- Implemented tracing of PRRTE task states at runtime
- Scheduling task across DVM becomes dominant at scale
- Average scheduling time of a task across the DVM is 0.2s
- Sequential scheduling times aggregate at runtime
- Opportunity for concurrent task scheduling across DVMs



RP+PRRTE Performance: Resource Utilization (RU)



- RU inversely proportional to TTX
- RU progressively dominated by preparing execution, i.e., RP wait time
- Removing wait time improves RU from 25.6% to 63.5% for 16k tasks
- RP scheduling is the new dominant overhead: addressed in latest release.



Conclusions

- Baseline characterization of the performance of RP, JSM and PRRTE integration on Summit when executing many-task workloads.
- Results:
  - Better scalability of PRRTE for > 987 concurrent task executions
  - PRRTE overheads are negligible when compared to aggregated overheads
  - PRRTE open source code enables reduction of aggregated overheads
- Planned work:
  - Support of several INCITE and Exascale compute projects
  - Partitioning of RP on Summit to support scaling up to whole Summit
  - Improvement of RP scheduler to support heterogeneous/dynamic workloads

Tasks / Nodes	Agent Nodes	Pilot Startup	Warmup	Prep. Execution	Exec. RP	Exec. PRRTE	Exec. Cmd	Unschedule	Draining	Pilot Termination	Idle
1024 / 26	3.846%	3.630%	1.680%	4.510%	0.016%	0.002%	**73.999** %	0.001%	6.149%	0.812%	5.355%
2048 / 51	1.961%	3.622%	1.603%	9.800%	0.011%	0.004%	**65.313** %	0.000%	11.356%	0.867%	5.462%
4096 / 101	0.990%	2.698%	1.398%	16.178%	0.013%	0.002%	**54.797** %	0.000%	17.798%	0.534%	5.593%
8192 / 202	0.495%	2.076%	1.954%	23.375%	0.021%	0.002%	**39.990** %	0.001%	25.570%	0.396%	6.120%
16384 / 410	0.244%	1.271%	3.309%	28.779%	0.021%	0.002%	**25.596** %	0.001%	32.752%	0.256%	7.771%
16384 / 410	1.013%	3.265%	6.314%	2.345%	2.421%	4.988%	**63.557** %	0.286%	11.526%	0.800%	3.485%

Table 1: Experiments 3–4: Resource utilization (RU) expressed as the percentage of resources used of blocked by RP, PRRTE and the workload. Last line shows optimized run of Experiment 4.

Thank you

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- Experiments data: https://github.com/radical-experiments/summit_jsrun_prte
- OpenPMIx PRRTE: https://github.com/openpmix/prrte
- RADICAL-Pilot: https://github.com/radical-cybertools/radical.pilot
- RADIAL Cybertools: https://radical-cybertools.github.io/