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# Scalability and efficiency challenges for the exascale supercomputing system: practice of a parallel supporting environment on the Sunway exascale prototype system

**Key words:** Parallel computing; Sunway; Ultra-large-scale; Supercomputer

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# Motivation

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- ❑ The growth in the scale of the exascale system will release huge computing power. Taking into account the **scalability and efficiency of parallel applications** under such a huge parallel scale raises great challenges to the design of the exascale system.
- ❑ In addition, with the increasing demand for computing power in artificial intelligence (AI) applications, **the fusion of AI and high-performance computing (HPC) applications** has become an important breakthrough direction for HPC applications. It is also a challenge to support the high scalability and efficiency of AI applications in the exascale era of HPC.

# 1) System and framework

- ❑ The **Sunway exascale prototype system (SEPS)** is a small-scale verification system designed according to the exascale application requirements, and can be scaled up to the exascale level.
- ❑ The **parallel supporting environment** is composed of the parallel operating system, distributed storage system, debugging and tuning system, scientific computing parallel framework, and AI ecosystem.

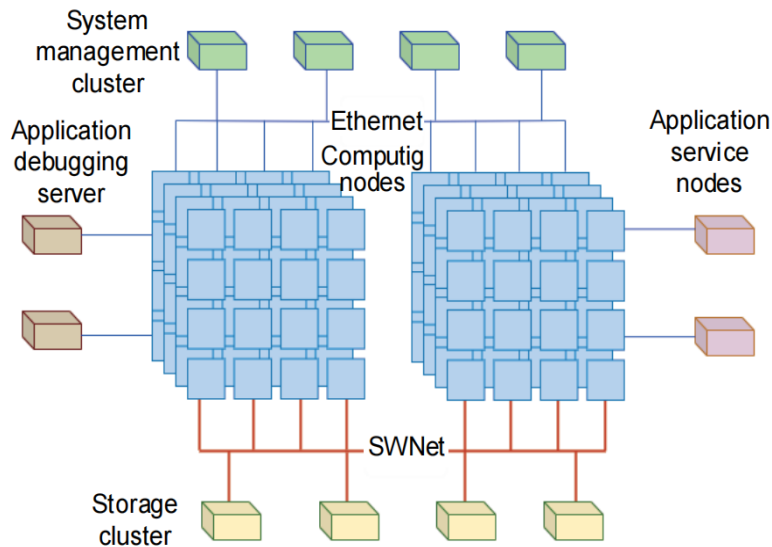


Fig. 1 Architecture of the Sunway exascale prototype system

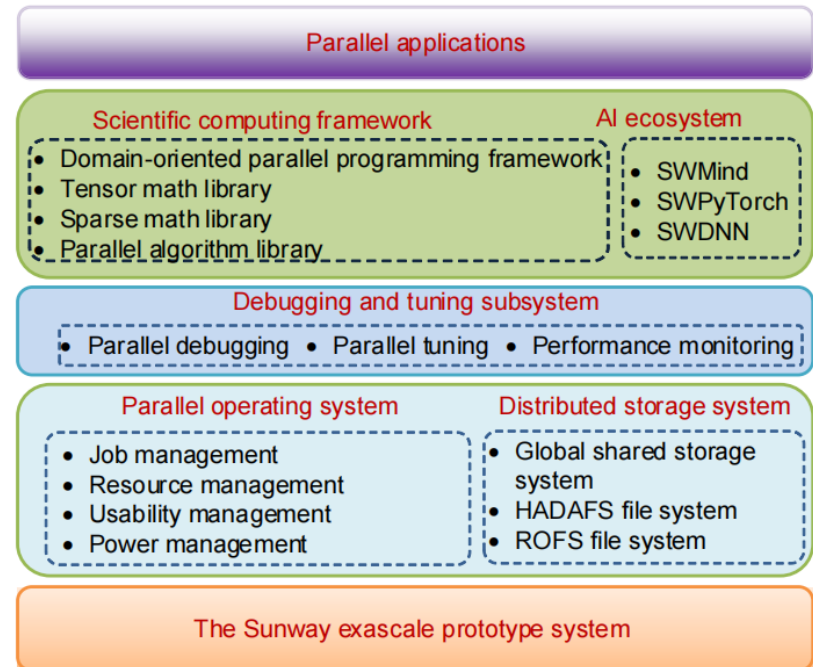


Fig. 2 Components of the parallel supporting environment

## 2) Design of the parallel supporting environment

- ❑ The resource management for the whole system on SPES enables users to execute their jobs concurrently and achieve **the unified management, monitoring, and on-demand allocation** for many-core computing nodes.
- ❑ SEPS carries a hybrid storage system, consisting of **a global file system (GFS), a burst buffer file system (HADAFS), and a read-only file system (ROFS)**.

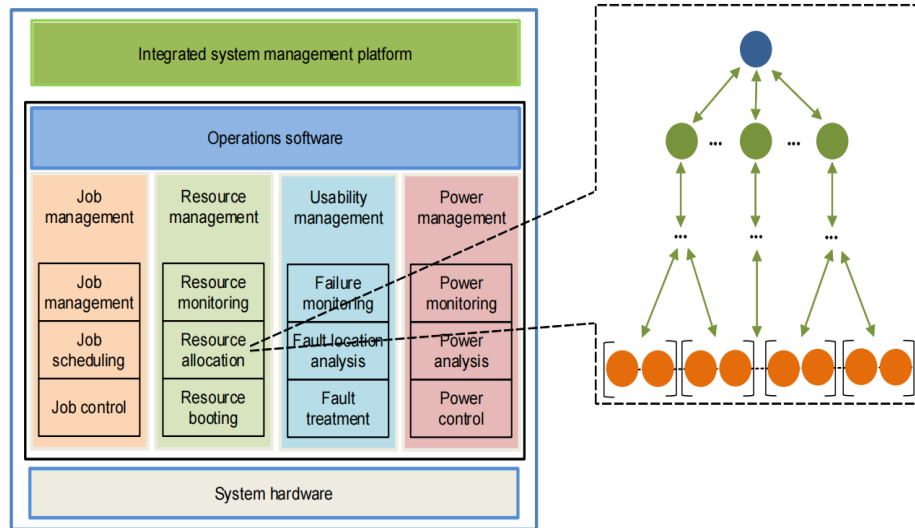


Fig. 3 Parallel operating system structure

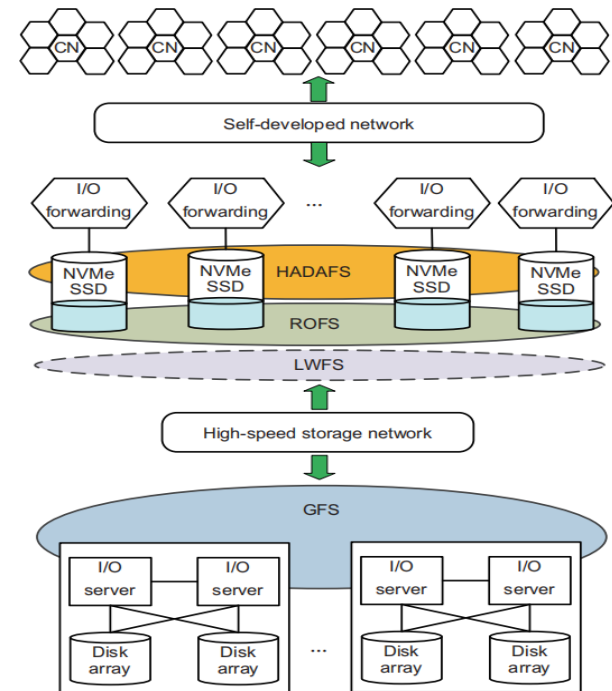


Fig. 4 Sunway storage architecture

## 2) Design of the parallel supporting environment

- ❑ The debugging and tuning subsystem provides developers with tools to **develop a large-scale application in less time**. Debugger, parallel debugging tool, and large-scale lightweight debugging tool make up the debugging part. They support **single-node applications**, **medium-scale applications**, and **large-scale applications**, respectively.
- ❑ The framework is composed mainly of two parts. One part is a **domain-oriented** parallel programming framework. The other part is the **kernel-level** parallel programming framework, including the tensor math library, sparse math library, and parallel algorithm library.

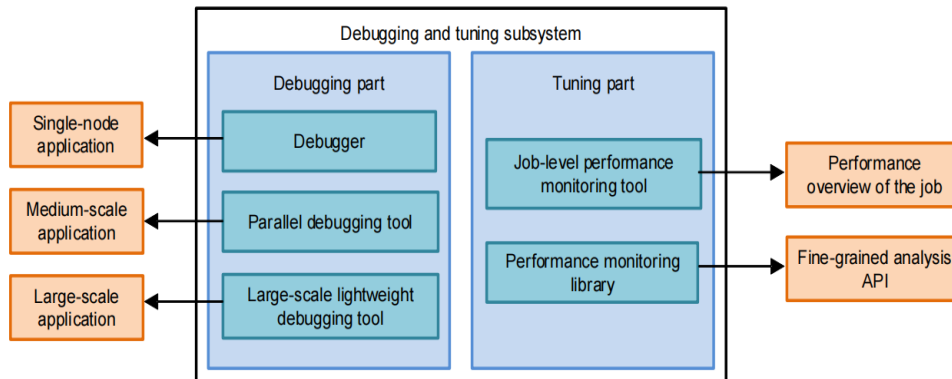


Fig. 5 Debugging and tuning subsystem

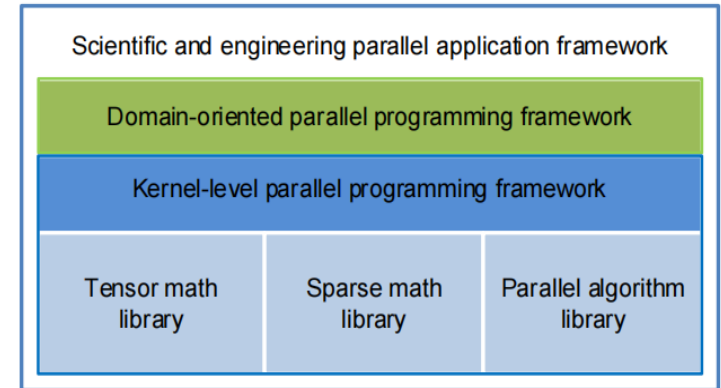


Fig. 6 Scientific computing parallel framework

### 3) Optimization technologies (I/O optimization)

- ❑ LIBIO calls the functions of the LWFS client port in a library manner, including **an application request intercepting component and a standard LWFS client port component**.
- ❑ When LIBIO is used, **the user does not need to modify the code**; the user needs to just link the LIBIO library in the compilation stage.
- ❑ The single-process bandwidth of a computing node **is increased by more than twice**, and the aggregate bandwidth of a single computing node **is increased by more than five times**.

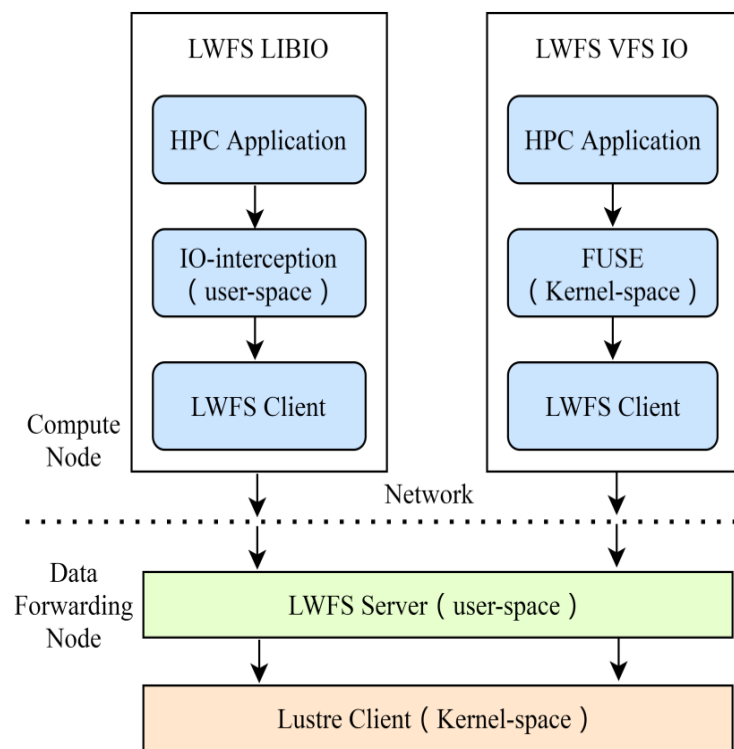


Fig. 7 Software architecture of LWFS LIBIO

# 3) Optimization technologies (multi-level parallelization mode)

- ❑ At the first level, the computing tasks in the specific application **are divided into multiple independent tasks** according to physical or geometry characteristics.
- ❑ At the second level, i.e., processlevel (MPI) parallelism, the independent task within the subgroup **is mapped to each MPI process**.
- ❑ The third level is **thread-level (CPE) parallelism**.

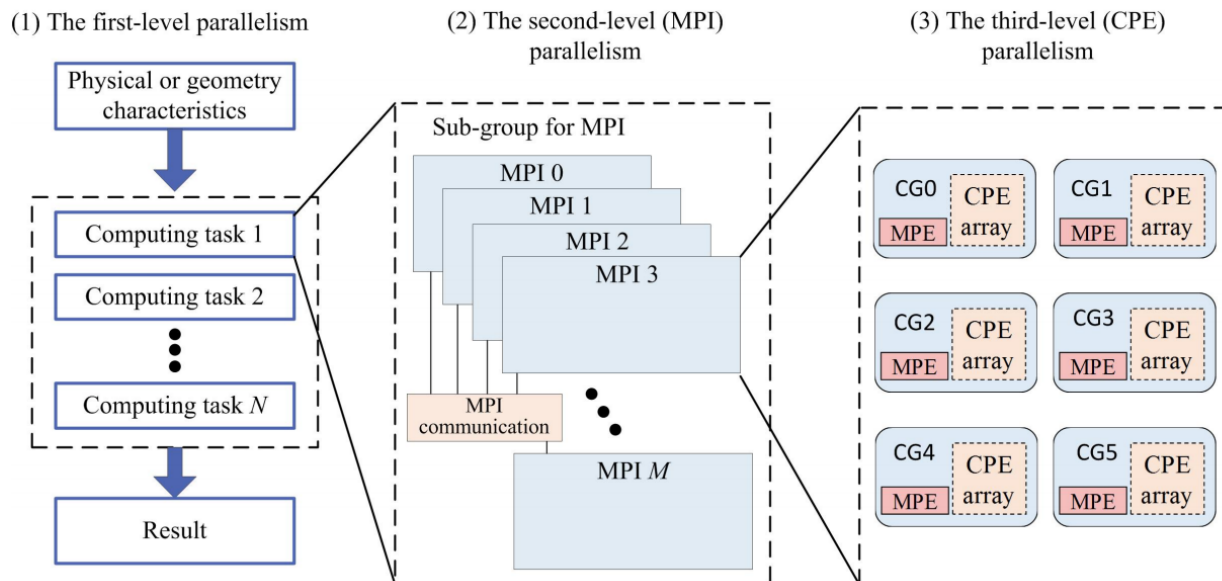
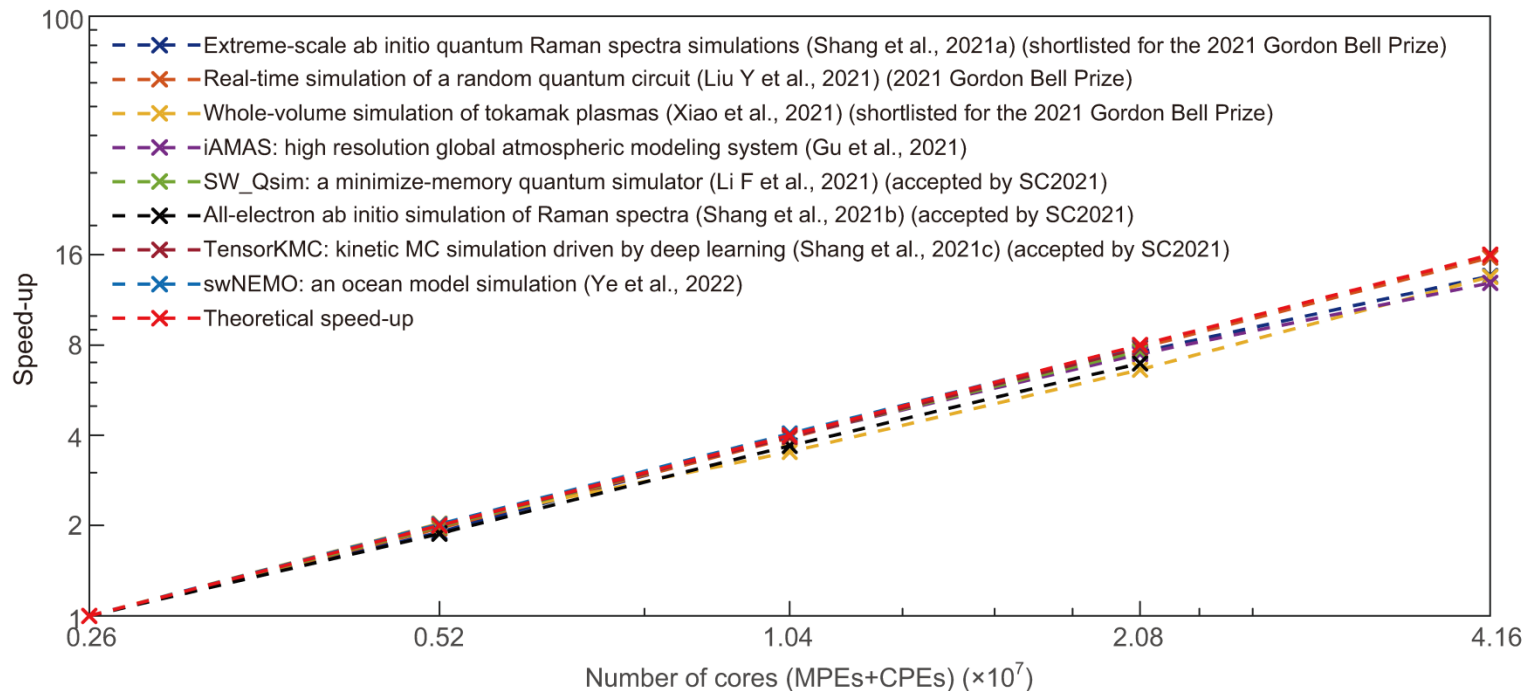


Fig. 8 Multi-level parallelization mode

# 4) Major results

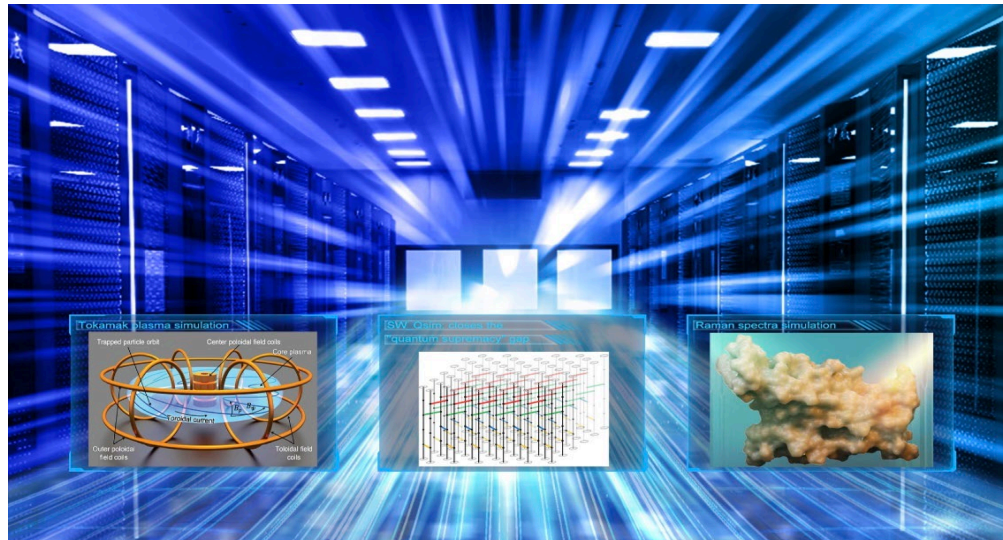
- These applications show great scalability potential in large-scale systems.
- Among them, **the random quantum circuit (RQC) simulation, Raman spectra simulation, and tokamak plasmas simulation** have all been shortlisted for the 2021 Gordon Bell Prize due to significant progress in these fields.

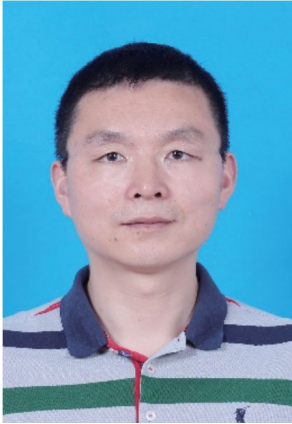


**Fig. 9 Expected scalability and efficiency of multiple outstanding applications on SEPS**

# Conclusions and future outlook

- ❑ This paper introduces the design of a parallel application support environment of SEPS and proposes **the key technologies of software in guaranteeing the scalability and efficiency of exascale applications.**
- ❑ Looking to the future, new complex applications reveal novel characteristics, such as computation and **data movement varying with time** and **discreteness and sparseness caused by data non-locality.** Given these new features, we will carry out research on novel parallel algorithms and parallel supporting software design and optimization methods.





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