# openEuler 24.03 LTS SP2 Technical White Paper

## 1 Introduction

The openEuler open source community is incubated and operated by the OpenAtom Foundation.

openEuler is a digital infrastructure OS that fits into any server, cloud computing, edge computing, and embedded deployment. This secure, stable, and easy-to-use open source OS is compatible with multiple computing architectures. openEuler suits operational technology (OT) applications and enables the convergence of OT and information and communications technology (ICT).

The openEuler open source community is a portal available to global developers, with the goal of building an open, diversified, and architecture-inclusive software ecosystem for all digital infrastructure scenarios. It has a rich history of helping enterprises develop their software, hardware, and applications.

The openEuler open source community was officially established on December 31, 2019, with the original focus of innovating diversified computing architectures.

On March 30, 2020, the Long Term Support (LTS) version openEuler 20.03 was officially released, which was a new Linux distribution with independent technology evolution.

Later in 2020, on September 30, the innovative openEuler 20.09 version was released through the collaboration efforts of multiple companies, teams, and independent developers in the openEuler community. The release of openEuler 20.09 marked a milestone not only in the growth of the openEuler community, but also in the history of open sourced software in China.

On March 31, 2021, the innovative kernel version openEuler 21.03 was released. This version is enhanced in line with Linux kernel 5.10 and also incorporates multiple new features, such as live kernel upgrade and tiered memory expansion. These features improve multi-core performance and deliver the computing power of one thousand cores.

Fast forward to September 30, 2021, openEuler 21.09 was released. This premium version is designed to supercharge all scenarios, including edge and embedded devices. It enhances server and cloud computing features, and incorporates key technologies including cloud-native CPU scheduling algorithms for hybrid service deployments and KubeOS for containers.

On March 30, 2022, openEuler 22.03 LTS was released based on Linux kernel 5.10. Designed to meet all server, cloud, edge computing, and embedded workloads, openEuler 22.03 LTS is an all-scenario digital infrastructure OS that unleashes premium computing power and resource utilization.

On September 30, 2022, openEuler 22.09 was released to further enhance all-scenario innovations.

On December 30, 2022, openEuler 22.03 LTS SP1 was released, which is designed for hitless porting with best-of-breed tools.

On March 30, 2023, openEuler 23.03 was released. Running on Linux kernel 6.1, it streamlines technical readiness for Linux kernel 6.x and facilitates innovations for hardware adaptation and other technologies.

On June 30, 2023, openEuler 22.03 LTS SP2 was released, which enhances scenario-specific features and increases system performance to a higher level.

Later on September 30, 2023, the openEuler 23.09 innovation version was released based on Linux kernel 6.4. It provides a series of brand-new features to further enhance developer and user experience.

On November 30, 2023, openEuler 20.03 LTS SP4 was released, an enhanced extension of openEuler 20.03 LTS. openEuler 20.03 LTS SP4 provides excellent support for server, cloud native, and edge computing scenarios.

On December 30, 2023, openEuler 22.03 LTS SP3 was released. Designed to improve developer efficiency, it features for server, cloud native, edge computing, and embedded scenarios.

On May 30, 2024, openEuler 24.03 LTS was released. This version is built on Linux kernel 6.6 and brings new features for server, cloud, edge computing, AI, and embedded deployments to deliver enhanced developer and user experience.

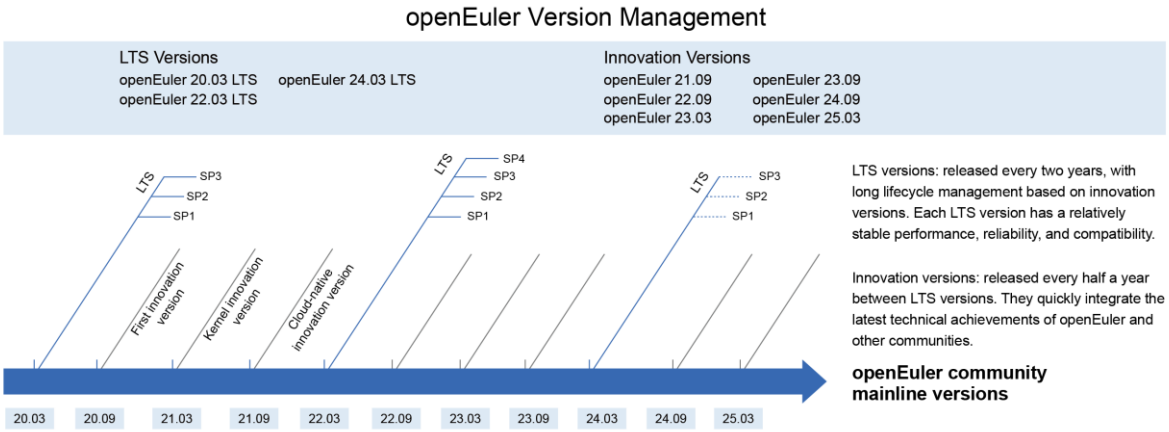
On June 30, 2024, openEuler 22.03 LTS SP4 was released. Designed to improve developer efficiency, it further extends features for server, cloud native, edge computing, and embedded scenarios.

On September 30, 2024, openEuler 24.09 was released. It is an innovation version built based on Linux kernel 6.6 and brings more advanced features and functions.

On December 30, 2024, openEuler 24.03 LTS SP1 was released. This enhanced and extended version of openEuler 24.03 LTS is developed on Linux kernel 6.6 and designed for server, cloud, edge computing, and embedded deployments. It offers new features and enhanced functions that streamline processes across a range of domains.

On March 30, 2025, openEuler 25.03 was released. It is an innovation version designed based on Linux kernel 6.6 and is suited for server, cloud, edge, and embedded scenarios. It provides a variety of new features and functions and brings brand-new experience to developers and users in diverse industries.

More recently on June 30, 2025, openEuler 24.03 LTS SP2 was released. It is an enhanced version of 24.03 LTS based on the Linux 6.6 kernel. It is designed for server, cloud, AI, and embedded scenarios, introducing new functions and features covering kernel optimization, heterogeneous collaborative inference, high-density many-core computing, confidential containers, and multi-core and multi-instance hybrid deployment. This latest openEuler release offers enhanced experience for developers and users across various industries.

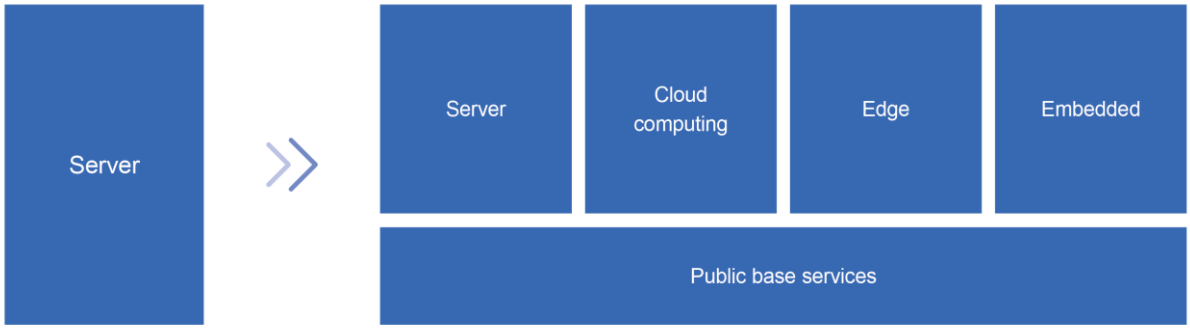


As an OS platform, openEuler releases an LTS version every two years. Each LTS version provides enhanced specifications and a secure, stable, and reliable OS for enterprise users.

openEuler is built on tried-and-tested technologies. A new openEuler innovation version is released every 6 months to quickly integrate the latest technical achievements of openEuler and other communities. The innovative tech is first verified in the openEuler open source community as a single open source project, and then these features are added to each new release, enabling community developers to obtain the source code.

Technical capabilities are first tested in the open source community, and continuously incorporated into each openEuler release. In addition, each release is built on feedback given by community users to bridge the gap between innovation and the community, as well as improve existing technologies. openEuler is both a release platform and incubator of new technologies, working in a symbiotic relationship that drives the evolution of new versions.

## Innovative Platform for All Scenarios




openEuler supports multiple processor architectures (x86, Arm, SW64, RISC-V, LoongArch, and PowerPC), as part of a focus to continuously improve the ecosystem of diversified computing power.

The openEuler community is home to an increasing number of special interest groups (SIGs), which are dedicated teams that help extend the OS features from server to cloud computing, edge computing, and embedded scenarios. openEuler is built to be used in any scenario.

The OS is a perfect choice for ecosystem partners, users, and developers who plan to enhance scenario-specific capabilities. By creating a unified OS that supports multiple devices, openEuler hopes to enable a single application development for all scenarios.

## Open and Transparent: Open Source Software Supply Chain

The process of building an open source OS relies on supply chain aggregation and optimization. To ensure reliable open source software or a large-scale commercial OS, openEuler comprises a complete lifecycle management that covers building, verification, and distribution. The brand regularly reviews its software dependencies based on user scenarios, organizes the upstream community addresses of all the software packages, and verifies its source code by comparing it to that of the upstream communities. The build, runtime dependencies, and upstream communities of the open source software form a closed loop, realizing a complete, transparent software supply chain management.

# 2 Platform Architecture

## System Framework

openEuler is an innovative open source OS platform built on kernel innovations and a solid cloud base to cover all scenarios. It is built on the latest trends of interconnect buses and storage media, and offers a distributed, real-time acceleration engine and base services. It provides competitive advantages in edge and embedded scenarios, and is the first step to building an all-scenario digital infrastructure OS.

openEuler 24.03 LTS SP2 runs on Linux kernel 6.6 and provides POSIX-compliant APIs and OS releases for server, cloud native, edge, and embedded environments. It is a solid foundation for intelligent collaboration across hybrid and heterogeneous deployments. openEuler 24.03 LTS SP2 is equipped with a distributed soft bus and K3s edge-cloud collaboration framework, among other premium features, making it a perfect choice for collaboration over digital infrastructure and everything connected models.

In the future, the openEuler open source community will continue to innovate, aiming to promote the ecosystem and consolidate the digital infrastructure.

**Cloud base:**

- **KubeOS for containers**: In cloud native scenarios, the OS is deployed and maintained in containers, allowing the OS to be managed based on Kubernetes, just as service containers.
- **Secure container solution**: Compared with the traditional Docker+QEMU solution, the iSulad+shimv2+StratoVirt secure container solution reduces the memory overhead and boot time by 40%.
- **Dual-plane deployment tool eggo**: OSs can be installed with one click for Arm and x86 hybrid clusters, while deployment of a 100-node cluster is possible within just 15 minutes.

**New scenarios:**

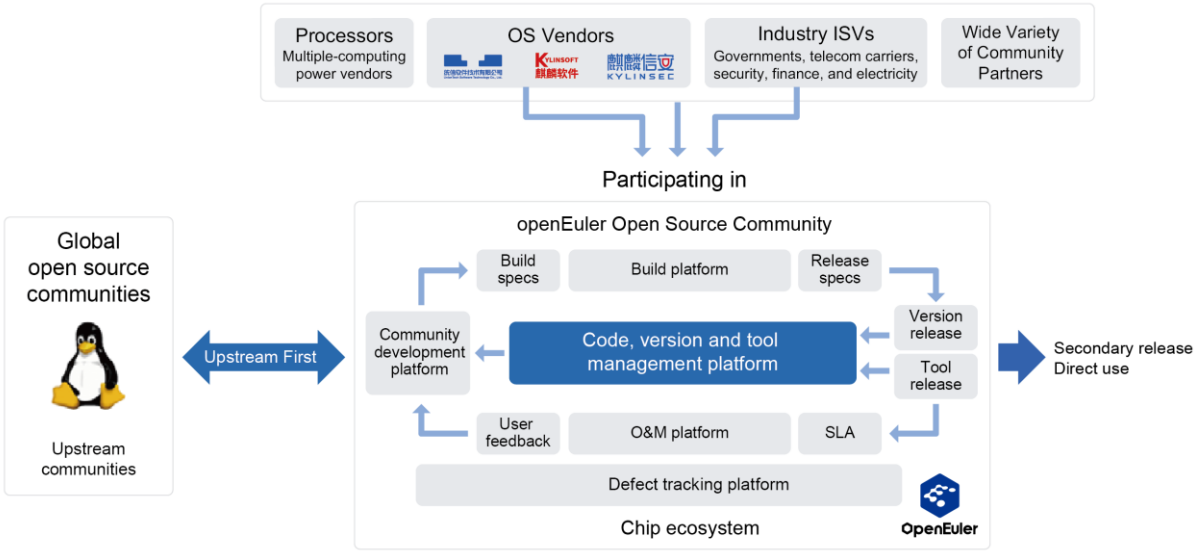
- **Edge computing**: openEuler 24.03 LTS SP1 Embedded is released for edge computing scenarios. It integrates the K3s edge-cloud collaboration framework to provide unified management, provisioning of edge and cloud applications, and other capabilities.
- **Embedded**: openEuler 24.03 LTS SP1 Embedded is released for embedded scenarios, helping compress images to under 5 MB and shorten the image loading time to under 5 seconds.
- **AI-native OS**: The OS enables AI software stacks with out-of-the-box availability. Heterogeneous convergence of memory, scheduling, and training/inference resources reduces AI development costs and improves efficiency. The intelligent interaction platform of the OS streamlines development and administration.

**Flourishing community ecosystem:**

- **Desktop environments**: UKUI, DDE, Kiran-desktop, and GNOME.
- **openEuler DevKit**: Supports OS migration, compatibility assessment, and various development tools such as secPaver which simplifies security configuration.

## Platform Framework

The openEuler open source community partners with upstream and downstream communities to advance the evolution of openEuler versions.




## Hardware Support

The openEuler open source community works with multiple vendors to build a vibrant southbound ecosystem. With participation of major chip vendors including Intel and AMD, all openEuler versions support x86, Arm, ShenWei, Loongson, and RISC-V CPU architectures, and a wide range of CPU chips, such as Loongson 3 series, Zhaoxin KaiXian and KaiSheng, Intel Sierra Forest and Granite Rapids, and AMD EPYC 4/5. openEuler can run on servers from multiple hardware vendors and is compatible with NIC, RAID, Fibre Channel, GPU & AI, DPU, SSD, and security cards.

openEuler supports the following CPU architectures:

| Hardware Type | x86_64 | AArch64 | LoongArch | SW64 | RISC-V |
|---|---|---|---|---|---|
| CPU | Intel, AMD, Hygon, Zhaoxin | Kunpeng, Phytium | Loongson | ShenWei | Sophgo, THead, etc. |

Visit https://www.openeuler.org/en/compatibility/ to see the full hardware list.

# 3 Operating Environments

## Servers

To install openEuler on a physical machine, check that the physical machine meets the compatibility and hardware requirements.

For a full list, visit https://openeuler.org/en/compatibility/.

| Item | Configuration Requirement |
| --- | --- |
| Architecture | AArch64, x86_64, RISC-V, LoongArch64, SW64 |
| Memory | ≥ 4 GB |
| Drive | ≥ 20 GB |

## VMs

Verify VM compatibility when installing openEuler.

Hosts running on openEuler 24.03 LTS SP2 support the following software packages:

- libvirt-9.10.0-16.oe2403sp2
- libvirt-client-9.10.0-16.oe2403sp2
- libvirt-daemon-9.10.0-16.oe2403sp2
- qemu-8.2.0-36.oe2403sp2
- qemu-img-8.2.0-36.oe2403sp2

openEuler 24.03 LTS SP2 is compatible with the following guest OSs for VMs:

| Guest OS | Architecture |
| --- | --- |
| CentOS 6 | x86_64 |
| CentOS 7 | AArch64 |
| CentOS 7 | x86_64 |
| CentOS 8 | AArch64 |
| CentOS 8 | x86_64 |
| Windows Server 2016 | x86_64 |
| Windows Server 2019 | x86_64 |

| Item | Configuration Requirement |
| --- | --- |
| Architecture | AArch64, x86_64 |
| CPU | ≥ 2 CPUs |
| Memory | ≥ 4 GB |
| Drive | ≥ 20 GB |

## Edge Devices

To install openEuler on an edge device, check that the edge device meets the compatibility and minimum hardware requirements.

| Item | Configuration Requirement |
| --- | --- |
| Architecture | AArch64, x86_64 |
| Memory | ≥ 4 GB |
| Drive | ≥ 20 GB |

## Embedded Devices

To install openEuler Embedded on an embedded device, check that the embedded device meets the compatibility and minimum hardware requirements.

| Item | Configuration Requirement |
| --- | --- |
| Architecture | AArch64, AArch32, x86_64 |
| Memory | ≥ 512 MB |
| Drive | ≥ 256 MB |

# 4 Scenario-specific Innovations

## AI

AI is redefining OSs by powering intelligent development, deployment, and O&M. openEuler supports general-purpose architectures like Arm, x86, and RISC-V, and next-gen AI processors like NVIDIA and Ascend. Further, openEuler is equipped with extensive AI capabilities that have made it a preferred choice for diversified computing power.

## OS for AI

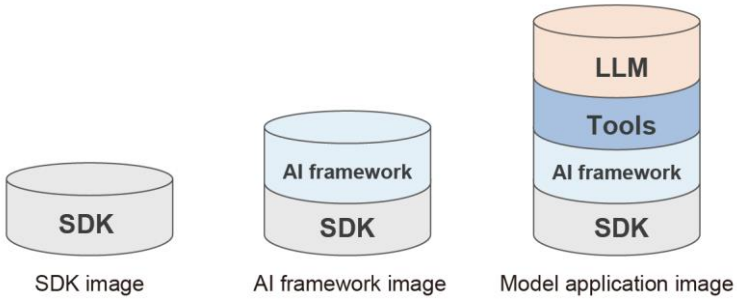
### Ready-to-Use Availability

openEuler offers an efficient development and runtime environment that containerizes software stacks of AI platforms with out-of-the-box availability. It also provides various AI frameworks to facilitate AI development.

#### Feature Description

openEuler supports TensorFlow, PyTorch, and MindSpore frameworks and software development kits (SDKs) of major computing architectures, such as Compute Architecture for Neural Networks (CANN) and Compute Unified Architecture (CUDA), to make it easy to develop and run AI applications.

Environment setup is further simplified by containerizing software stacks. openEuler provides three types of container images:




- **SDK images**: Use openEuler as the base image and install the SDK of a computing architecture, for example, Ascend CANN and NVIDIA CUDA.
- **AI framework images**: Use an SDK image as the base and install AI framework software, such as PyTorch and TensorFlow. You can use an AI framework image to quickly build a distributed AI framework, such as Ray.
- **Model application images**: Provide a complete set of toolchains and model applications.

For details, see the openEuler AI Container Image User Guide.

### Application Scenarios

openEuler uses AI container images to simplify deployment of runtime environments. You can select the container image that best suits your requirements and complete the deployment in a few simple steps.

- **SDK images**: You can develop and debug Ascend CANN or NVIDIA CUDA applications using an SDK image, which provides a compute acceleration toolkit and a development environment. These containers offer an easy way to perform high-performance computing (HPC) tasks, such as large-scale data processing and parallel computing.
- **AI framework images**: This type of containers is designed to support AI model development, training, and inference.
- **Model application images**: Such an image contains a complete AI software stack and purpose-built models for model inference and fine-tuning.

## sysHAX

### Feature Description

The sysHAX large language model (LLM) heterogeneous acceleration runtime enhances model inference performance in single-server, multi-xPU setups by optimizing Kunpeng + xPU (GPU/NPU) resource synergy.

- Operator pushdown acceleration: Adapts to vLLM v0.6.6 to optimize the scheduling engine, shortening latency on CPUs.
- CPU inference acceleration: Improves CPU throughput via NUMA-aware scheduling, parallelized matrix operations, and SVE-optimized inference operators.
- Heterogeneous converged scheduling: When GPUs are fully loaded, the prefill phase of an inference request can be executed on GPUs while the decode phase is handled by CPUs.

## Application Scenarios

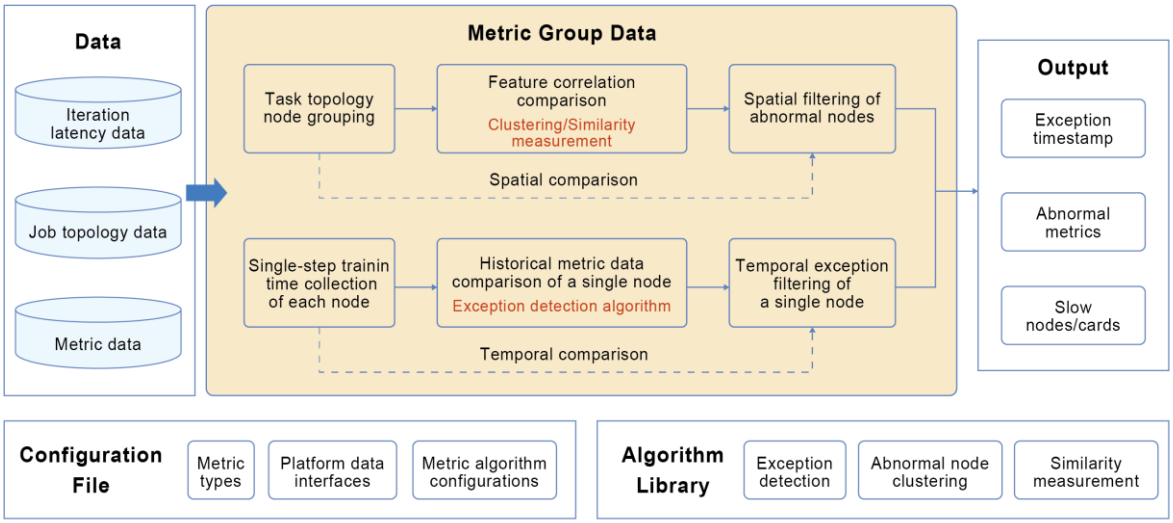
sysHAX is used to optimize Transformer models including DeepSeek, Qwen, Baichuan, and Llama. Its CPU inference acceleration capability has been adapted to DeepSeek 7B, 14B, and 32B and Qwen2.5 series models. sysHAX fits into the following application scenario:

Data centers: sysHAX assigns inference tasks to CPUs to fully utilize CPU resources and increase the concurrency and throughput of LLMs.

## Fault Detection by Group

Performance degradation during AI cluster training is inevitable and often results from a wide range of complex factors. Existing solutions rely on log analysis after performance degradation occurs. However, it can take 3 to 4 days from log collection to root cause diagnosis and issue resolution on the live network. To address these pain points, an online slow node detection solution is offered. This solution allows for real-time monitoring of key system metrics and uses model- and data-driven algorithms to analyze the observed data and pinpoint slow or degraded nodes. This facilitates system self-healing and fault rectification by O&M personnel.

## Feature Description




Grouped metric comparison helps detect slow nodes and cards in AI cluster training. This technology is built on Systrace and includes a configuration file, an algorithm library, and a slow node analysis mechanism based on both time and space dimensions. It outputs the exception timestamp, abnormal metrics, and IP addresses of slow nodes and cards. This technology enhances overall system stability and reliability.

- **Configuration file**: Contains the types of metrics to be observed, configuration parameters for the metric algorithms, and data interfaces, which are used to initialize the slow node detection algorithms.
- **Algorithm library**: Includes common time series exception detection algorithms, such as Streaming Peaks-over-Threshold (SPOT), k-sigma, abnormal node clustering, and similarity measurement.
- **Data**: Metric data collected from each node is represented by a time sequence.

- **Grouped metric comparison**: Supports spatial filtering of abnormal nodes and temporal exception filtering of a single node. Spatial filtering identifies abnormal nodes based on the exception clustering algorithm, while temporal exception filtering determines whether a node is abnormal based on the historical data of the node.

### Application Scenarios

Systrace provides capabilities for detecting slow nodes, displaying alarms, and writing exception information to drives.

**AI model training**: This feature quickly detects slow nodes for training jobs in large-scale AI clusters, facilitating system self-healing and fault rectification by O&M personnel.

**AI model inference**: This feature identifies performance degradation across multiple instances of the same model. By comparing resource usage of multiple instances, it quickly locates underperforming instances to aid inference task scheduling and enhance resource utilization.

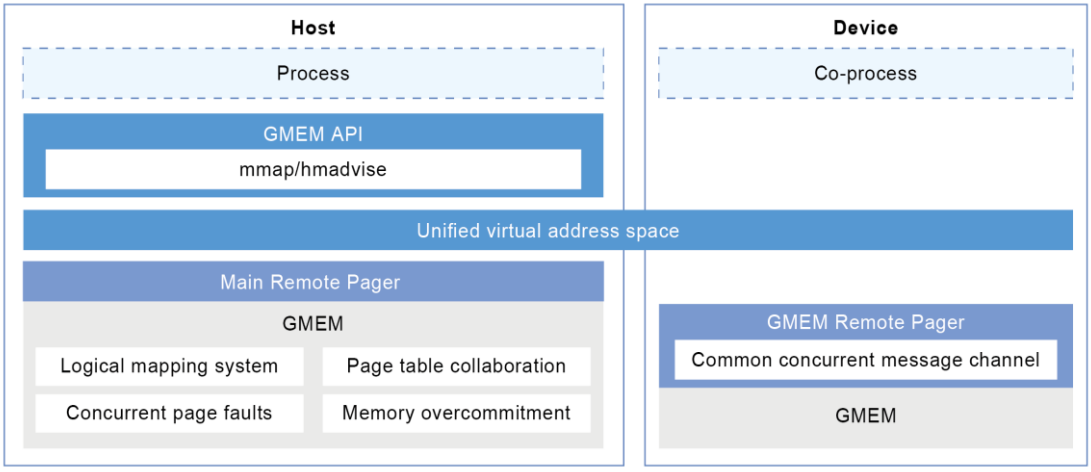
## GMEM

In the post-Moore era, there have been breakthroughs in GPUs, TPUs, FPGAs, and other dedicated heterogeneous accelerators. Similar to CPUs, these devices increase computing speeds by storing data in local memory (such as LPDDR SDRAM or HBM), but such design catalyzes more complicated memory systems. Modern memory systems have the following defects:

- Memory management is split between CPUs and accelerators. Explicit data migration makes it difficult to balance the usability and performance of accelerators' memory.
- The high bandwidth memory (HBM) available on accelerators is often insufficient for foundation models. Manual swapping is only feasible in limited scenarios and typically results in significant performance degradation.
- A large number of invalid data migrations occur in search & recommendation and big data scenarios, and no efficient memory pooling solution is available.

Heterogeneous Memory Management (HMM) is a Linux feature that is plagued by issues of poor programming, performance, and portability, while also relying heavily on manual tuning. As such, it is unfavored by most OS communities, and has fueled demand for an efficient solution for heterogeneous accelerators. Generalized Memory Management (GMEM) is one new option, which offers a centralized management mechanism for heterogeneous memory connections. GMEM APIs are compatible with native Linux APIs, and feature high usability, performance, and portability. After an accelerator calls GMEM APIs to connect its memory to the unified address space, the accelerator automatically obtains the programming optimization capability for heterogeneous memory, and does not need to execute the memory management framework multiple times. This greatly reduces development and maintenance costs. Developers can apply for and release a unified set of APIs to achieve heterogeneous memory programming without memory migrations. If the HBM of an accelerator is insufficient, GMEM can use the CPU memory as the accelerator cache to transparently over-allocate the HBM without manual swapping. GMEM offers an efficient memory pooling solution thanks to a shared memory pool that eliminates the need for duplicate migrations.

## Feature Description




GMEM enhances memory management in the Linux kernel. Its logical mapping system masks the differences between the ways how the CPU and accelerator access memory addresses. The Remote Pager memory message interaction framework provides the device access abstraction layer. In the unified address space, GMEM automatically migrates data to the OS or accelerator when data is to be accessed or paged.

- **GMEM**

  GMEM leverages the computing power of both CPUs and accelerators. It combines the two independent address spaces of the OS and accelerators into a unified virtual address space, to realize unified memory management and transparent memory access.

  GMEM uses a collection of new logical page tables to manage the unified virtual address space, ensuring data consistency between the page tables of different CPUs and micro architectures. Based on the memory access consistency mechanism of the logical page tables, the target memory space can be migrated between the host and accelerator using a kernel page fault handling procedure. If the accelerator's memory space is insufficient, the accelerator can borrow memory from the host and reclaim its cold memory to achieve memory overcommitment. This practice removes issues in which model parameters are restricted by the accelerator's memory, and reduces the cost of foundation model training.

  GMEM high-level APIs in the kernel allow the accelerator driver to directly use memory management functions by registering the MMU functions defined in the GMEM specification. With memory management functions, the accelerator can create logical page tables and perform memory overcommitment. The logical page tables decouple the high-layer logic of memory management from the CPU's hardware layer, so as to abstract the high-layer memory management logic that can be reused by different accelerators. This design only requires the accelerator to register bottom-layer functions, and does not need high-layer logic for the unified address space.

- **Remote Pager**

  Remote Pager is a memory message interaction framework that adopts message channel, process management, memory swap, and memory prefetch modules for the collaboration between the host and accelerator. It is enabled by the independent driver **remote_pager.ko**. The Remote Pager abstraction layer simplifies device adaptation by enabling third-party accelerators to easily access the GMEM system.

- **User APIs**

  To allocate the unified virtual memory, you can directly use the mmap system call. GMEM adds the flag (**MMAP_PEER_SHARED**) of allocating the unified virtual memory to mmap.

  The libgmem user-mode library provides the hmadvise API of memory prefetch semantics that helps optimize the accelerator memory access. For details, visit https://gitee.com/openeuler/libgmem/blob/master/README.md.

- **Constraints**

  GMEM supports 2 MB huge pages only. Therefore, transparent OS huge pages must be enabled on hosts and NPUs to use GMEM.

  The heterogeneous memory obtained using **MAP_PEER_SHARED** cannot be inherited during fork.

  For details about how to use GMEM, visit:

  https://gitee.com/openeuler/docs-centralized/tree/master/docs/en/docs/GMEM

### Application Scenarios

- Heterogeneous unified memory programming

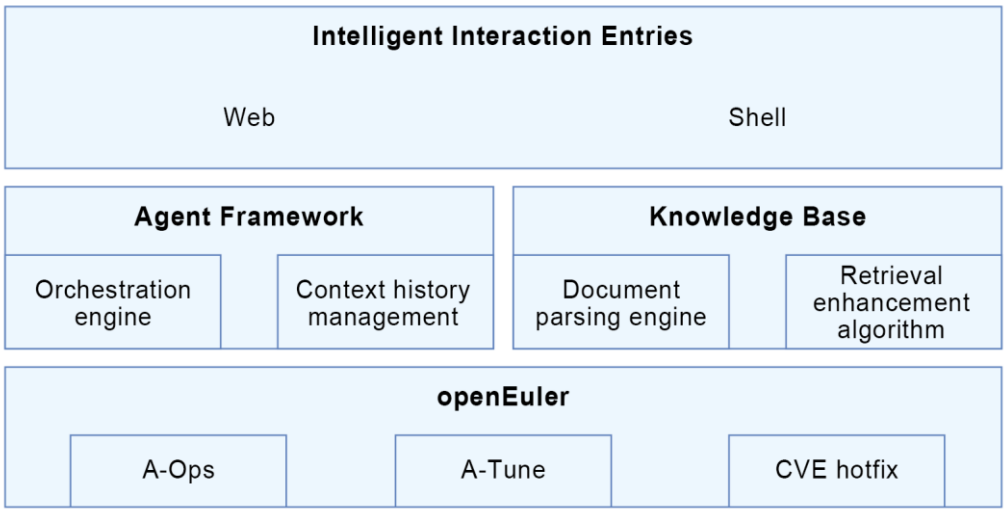
  To simplify heterogeneous memory programming, GMEM can allocate a unified virtual memory to CPUs and accelerators, which then share the same pointer. For example, an NPU memory management system can be connected to GMEM with just 100 lines of modified code in the NPU driver, a huge reduction on the original 4,000 lines in the memory management framework.

- Automatic memory overcommitment of an accelerator

  When a GMEM API is used to allocate memory to an application, the application is not limited by the physical memory capacity of the accelerator. Instead, the application can transparently over-allocate memory until the CPU's DRAM capacity is exhausted. GMEM swaps cold device memory pages out to the CPU memory to achieve high-performance and easy-to-start training and inference. This design makes GMEM deliver 1.6 times the performance of NVIDIA-UVM in ultra-large model training when the overcommitment ratio is 200%. (Test results compared the Ascend 910 NPU and NVIDIA A100 GPU under the same HBM conditions.)

## AI for OS

AI makes openEuler more intelligent. openEuler Intelligence is an AI-powered Q&A platform built on openEuler data. It supports intelligent question answering based on a knowledge base and enables workflow orchestration through semantic interfaces. Additionally, it integrates some system services to further improve the intelligence of openEuler.




## Intelligent Q&A

### Feature Description

The openEuler Intelligence system is accessible via web or shell.

- **Web**: Through the visual web entry, users can easily build and use the knowledge base, run automated tests on the knowledge base, and view test evaluation results. They can also register OpenAPI APIs and create workflow applications based on them. The web entry helps beginners access openEuler knowledge and leverage openEuler's AI capabilities effortlessly.
- **Shell**: Through the shell entry, users can use OpenAI API keys to trigger intelligent Q&A or orchestrated workflows within the agent framework. The shell entry allows O&M personnel to interact with openEuler in an OS-affinity and intelligent manner, simplifying operations and reducing O&M costs.

#### Intelligent Scheduling and Recommendation

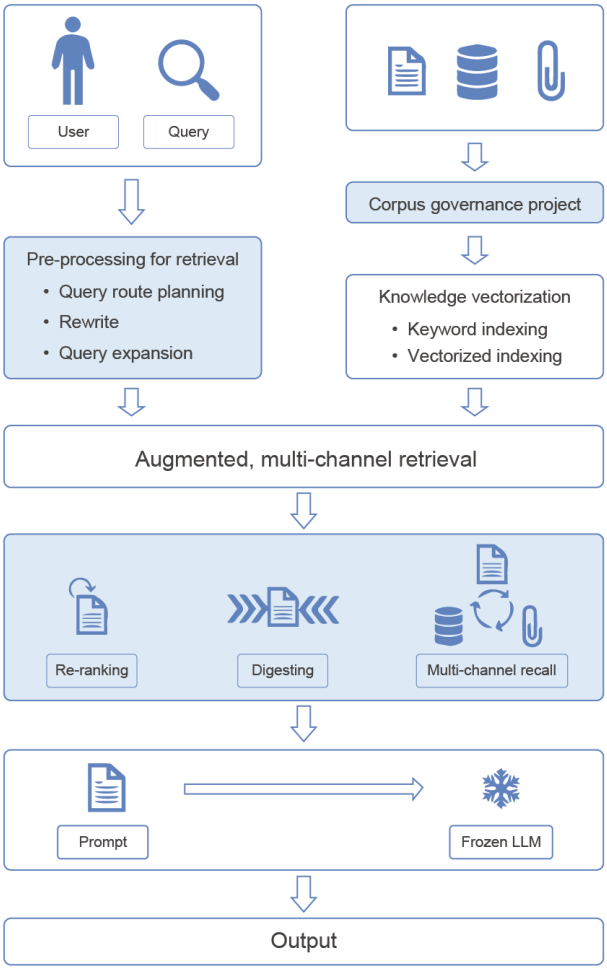
- **Intelligent scheduling**: openEuler Intelligence allows users to define multiple workflows within an application. When a query request is made, openEuler Intelligence automatically extracts the relevant parameters and selects the most suitable workflow to execute the query task.
- **Intelligent recommendation**: Based on users' query requests and workflow execution results, openEuler Intelligence recommends workflows that may be useful in future tasks, increasing the likelihood of task completion and making applications easier to use.

#### Workflows

- **Semantic interfaces**: A semantic interface contains natural language comments. openEuler Intelligence supports two methods for registering semantic interfaces. The first method allows users to register APIs with openEuler Intelligence as OpenAPI (3.0 or later) YAML files. When writing an OpenAPI YAML file, users can add natural language comments to the APIs. When these APIs are called, the foundation model selects the right APIs and sets their parameters based on the comments. The second method allows users to register functions with openEuler Intelligence as Python code, and this method provides a more user-friendly option for using openEuler Intelligence. The semantic interfaces generated in both methods can be orchestrated into workflows in a visualized manner.

- **Workflow orchestration and invocation**: openEuler Intelligence enables users to visually connect built-in semantic interfaces and user-registered interfaces to create workflows. Users can debug these workflows, and then release and use them as applications. When workflows are debugged and executed, intermediate results are displayed to help lower debugging costs and enhance the overall user experience.

**RAG**




Retrieval-augmented generation (RAG) is a technique for enhancing the long-term memory capability of large language models (LLMs). Used by the openEuler Intelligence system, RAG is essential to reducing model training costs and has the following highlights:

- **Pre-processing for retrieval**: When a user's query requests lacks sufficient information, it can be rewritten based on historical context and inferred intent to enhance retrieval accuracy.
- **Knowledge indexing**: For documents of various formats and content types, openEuler Intelligence offers document parsing capabilities such as summarization, text feature extraction, tree-structured parsing, and optical character recognition (OCR). These capabilities help generate segment-level feature indexes to increase hit rates.
- **Retrieval enhancement**: openEuler Intelligence supports eight retrieval methods. Among them, the methods using dynamic keyword weighting and LLM-based filtering significantly boost out-of-the-box accuracy.

- **Post-processing for retrieval**: For fragments with missing context, a uniform randomized context completion method is provided to enhance the completeness of fragment information and reduce hallucination in model fitting. For fragments (sets) with the maximum number of tokens, various methods are provided to enable intelligent Q&A for scenarios with limited resources. These methods include the reranking method based on the Jaccard distance, token compression method that removes common words and applies random discarding, and token truncation method based on binary search.

These capabilities enable RAG for the openEuler Intelligence system to accommodate to more document formats and content types, and enhance Q&A services with minimal impact on system load.

### Corpus Governance

Corpus governance is one of the basic RAG capabilities in the openEuler Intelligence system. It imports corpuses into the knowledge base in a supported format using context location extraction, text summarization, and OCR, increasing the retrieval hit rate.

- **Context location extraction**: The relative location relationship within a document is retained. Specifically, the global and local relative offsets of each segment are recorded to support context completion.
- **Text summarization**: Sliding windows and LLMs are used to generate text summaries for complex documents or segments, supplying foundational data for multi-level retrieval.
- **OCR augmentation**: For documents containing both images and text, summaries are generated based on image text and surrounding context to provide foundational data for answering image-related questions.

### Automated Testing

Automated testing is a core RAG capability in openEuler Intelligence. It detects shortcomings in the knowledge base and retrieval augmentation algorithms through automated dataset generation and evaluation.

- **Dataset generation**: After a user selects a parsed document, openEuler Intelligence randomly samples a portion of the parsing results and sends them to an LLM. The LLM then generates and filters Q&A pairs to create a high-quality test dataset that contains queries, reference answers, and original segments.
- **Test evaluation**: Automated tests are conducted using the user-generated dataset and the predefined parameters such as the retrieval augmentation algorithm, LLM, and top-k fragments. Tests score are calculated based on the queries, reference answers, original fragments, associated fragments, and model fitting results in the test dataset. After that, the test results are evaluated using metrics such as the precision rate, recall rate, fidelity value, explainability, longest common substring score, edit distance score, and Jaccard similarity coefficient.

## Application Scenarios

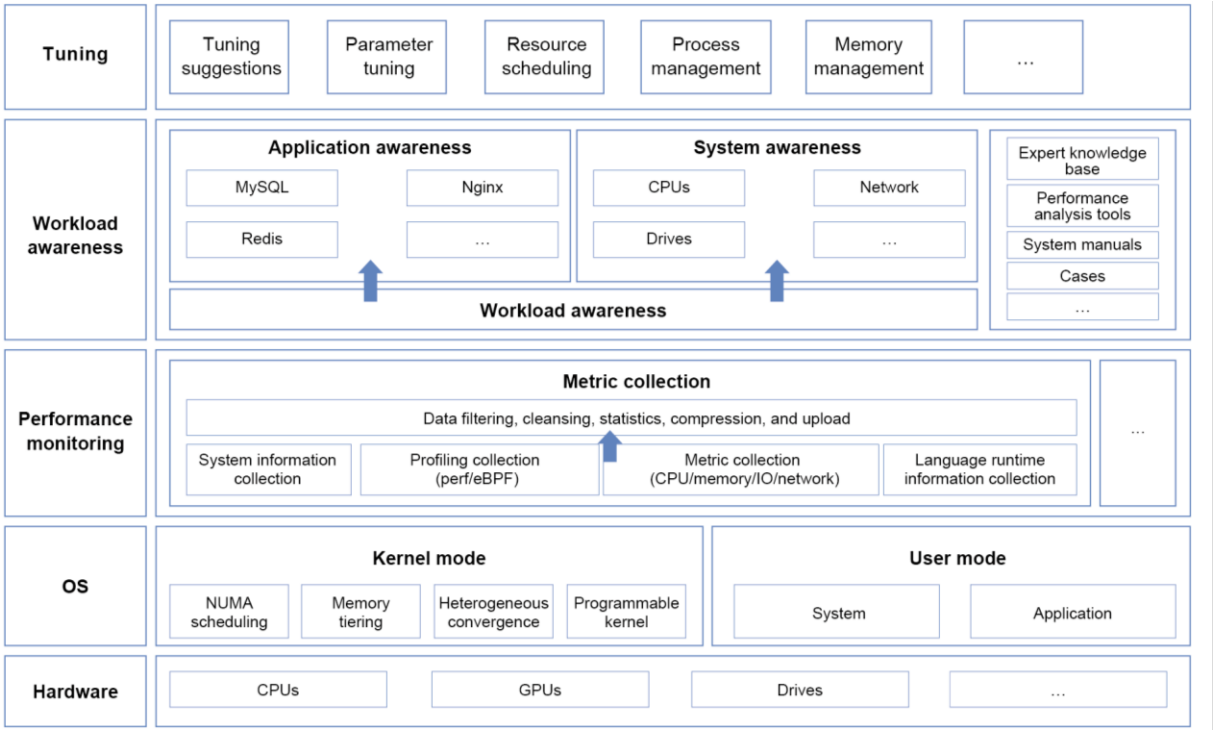
- **Common users** who are seeking best practices, such as porting applications to openEuler.
- **Developers** who want to learn contribution processes, key features, project development, and other extensive knowledge of openEuler.
- **O&M personnel** who aim to solve common problems and improve system management based on Q&A system suggestions.

For details, see the openEuler Intelligence Q&A User Guide.

# Intelligent Tuning

## Feature Description

The openEuler Intelligence system supports the intelligent shell entry. Through this entry, you can interact with openEuler Intelligence using a natural language and perform heuristic tuning operations such as performance data collection, system performance analysis, and system performance tuning.

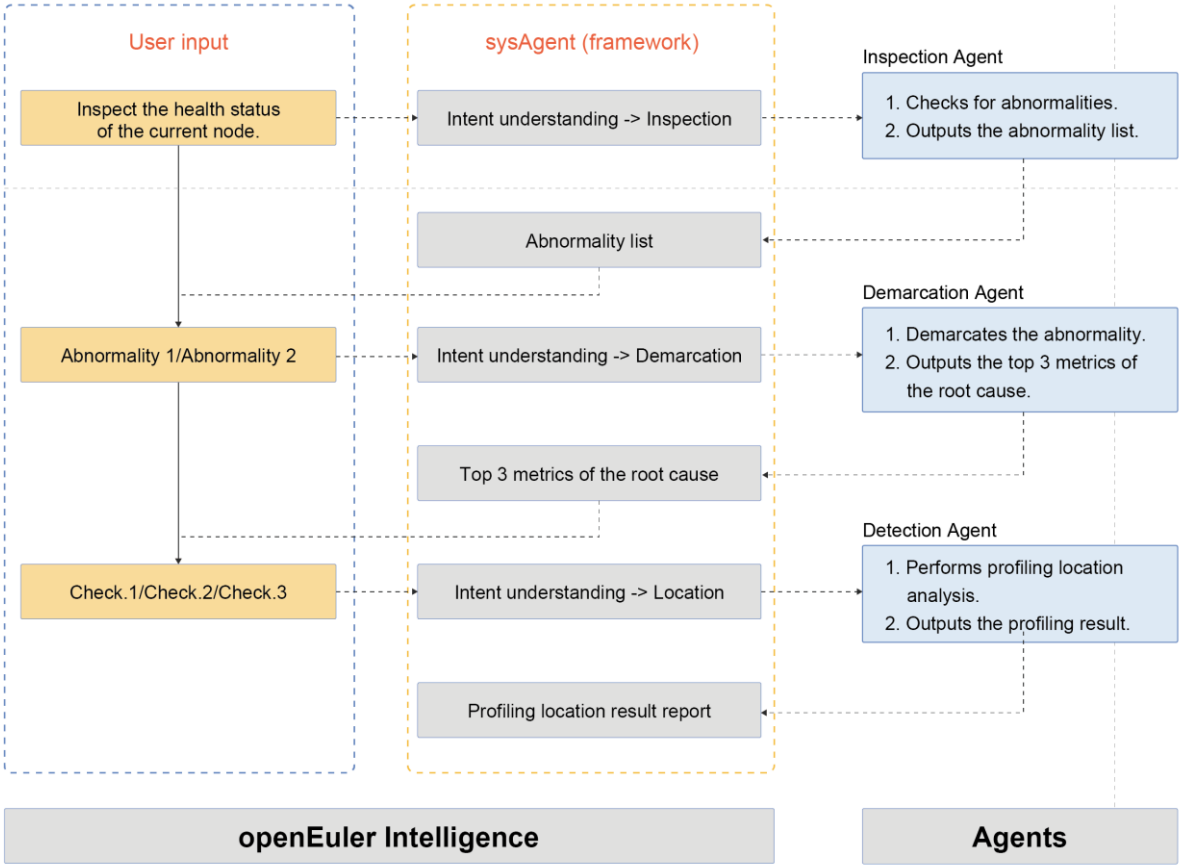



## Application Scenarios

- **Gaining insights from key performance metrics**: You can learn about the system performance status based on collected performance metrics like CPU, I/O, drive, network, and application.
- **Analyzing system performance**: Performance analysis reports are generated, making it easier to locate performance bottlenecks across the entire system and in individual applications.
- Receiving performance tuning suggestions: The openEuler Intelligence system generates a performance tuning script, which can be executed with one click to tune the system and specific applications.

# Intelligent Diagnosis

## Feature Description




1. **Inspection**: The Inspection Agent checks for abnormalities of designated IP addresses and provides an abnormality list that contains associated container IDs and abnormal metrics (such as CPU and memory).
2. **Demarcation**: The Demarcation Agent analyzes and demarcates a specified abnormality contained in the inspection result and outputs the top 3 metrics of the root cause.
3. **Location**: The Detection Agent performs profiling location analysis on the root cause, and provides useful hotspot information such as the stack, system time, and performance metrics related to the root cause.

## Application Scenarios

In openEuler 24.03 LTS SP2, the intelligent shell entry enables capabilities like single-node abnormality inspection, demarcation, and profiling location.

- The inspection capabilities refer to single-node performance metric collection, performance analysis, and abnormality inspection.
- The demarcation capability is to locate the root cause based on the abnormality inspection result and output the top 3 metrics of the root cause.
- The profiling location capability refers to using a profiling tool to locate the faulty modules (code snippets) based on the root cause.

# Intelligent Container Images

## Feature Description

The openEuler Intelligence system can invoke environment resources through a natural language, assist in pulling container images for local physical resources, and establish a development environment suitable for debugging on existing compute devices.

This system supports three types of containers, and container images have been released on Docker Hub. You can manually pull and run these container images.

- **SDK layer**: encapsulates only the component libraries that enable AI hardware resources, such as CUDA and CANN.
- **SDKs + training/inference frameworks**: accommodates TensorFlow, PyTorch, and other frameworks (for example, tensorflow2.15.0-cuda12.2.0 and pytorch2.1.0.a1-cann7.0.RC1) in addition to the SDK layer.
- **SDKs + training/inference frameworks + LLMs**: encapsulates several models (for example, llama2-7b and chatglm2-13b) based on the second type of containers.

The following table lists the container images supported by the openEuler Intelligence system:

| Registry | Repository | Image Name | Tag |
|---|---|---|---|
| docker.io | openeuler | cann | 8.0.RC1-oe2203sp4 |
| | | | cann7.0.RC1.alpha002-oe2203sp2 |
| docker.io | openeuler | oneapi-runtime | 2024.2.0-oe2403lts |
| docker.io | openeuler | oneapi-basekit | 2024.2.0-oe2403lts |
| docker.io | openeuler | llm-server | 1.0.0-oe2203sp3 |
| docker.io | openeuler | mlflow | 2.11.1-oe2203sp3 |
| | | | 2.13.1-oe2203sp3 |
| docker.io | openeuler | llm | chatglm2_6b-pytorch2.1.0.a1-cann7.0.RC1.alpha002-oe2203sp2 |
| | | | llama2-7b-q8_0-oe2203sp2 |
| | | | chatglm2-6b-q8_0-oe2203sp2 |
| | | | fastchat-pytorch2.1.0.a1-cann7.0.RC1.alpha002-oe2203sp2 |
| docker.io | openeuler | tensorflow | tensorflow2.15.0-oe2203sp2 |
| | | | tensorflow2.15.0-cuda12.2.0-devel-cudnn8.9.5.30-oe2203sp2 |
| docker.io | openeuler | pytorch | pytorch2.1.0-oe2203sp2 |
| | | | pytorch2.1.0-cuda12.2.0-devel-cudnn8.9.5.30-oe2203sp2 |
| | | | pytorch2.1.0.a1-cann7.0.RC1.alpha002-oe2203sp2 |

| Registry | Repository | Image Name | Tag |
| --- | --- | --- | --- |
| docker.io | openeuler | cuda | cuda12.2.0-devel-cudnn8.9.5.30-oe2203sp2 |

### Application Scenarios

- **Common openEuler operations**: Simplify the process of building a deep learning development environment while saving physical resources. For example, set up an Ascend development environment on openEuler.
- **openEuler development**: Developers familiarize themselves with the openEuler AI software stack to reduce the trial-and-error cost of installing components.

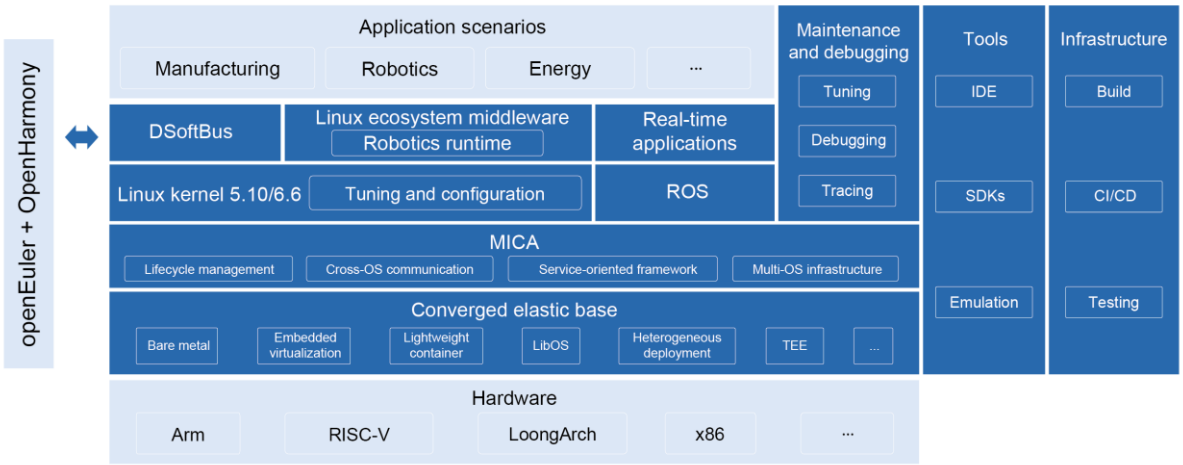
## Embedded

openEuler 24.03 LTS SP2 is suited for embedded applications, offering significant progress in southbound and northbound ecosystems, technical features, infrastructure, and implementation over previous generations.

openEuler Embedded provides a closed loop framework often found in operational technology (OT) applications such as manufacturing and robotics, whereby innovations help optimize its embedded system software stack and ecosystem. openEuler Embedded enhances its software package ecosystem by incorporating the oebridge feature, which supports online software installation from an openEuler mirror site. When building Yocto images, oebridge can be used to install openEuler RPM packages for easy image customization. openEuler Embedded also supports the oedeploy feature for quick deployment of AI and cloud-native software stacks. Kernel support in openEuler is enhanced by optimizing the meta-openeuler kernel configuration and the oeaware real-time tuning feature. These updates help control interference and improve real-time system responsiveness.

Future versions of openEuler Embedded will integrate contributions from ecosystem partners, users, and community developers, increase support for chip architectures such as LoongArch and more southbound hardware, and optimize industrial middleware, embedded AI, embedded edge, and simulation system capabilities.

## System Architecture



## Southbound Ecosystem

openEuler Embedded Linux supports mainstream processor architectures like AArch64, x86_64, AArch32, and RISC-V, and will extend support to LoongArch in the future. openEuler 24.03 and later versions have a rich southbound ecosystem and support chips from Raspberry Pi, HiSilicon, Rockchip, Renesas, TI, Phytium, StarFive, and Allwinner.

## Embedded Virtualization Base

openEuler Embedded uses an elastic virtualization base that enables multiple OSs to run on a system-on-a-chip (SoC). The base incorporates a series of technologies including bare metal, embedded virtualization, lightweight containers, LibOS, trusted execution environment (TEE), and heterogeneous deployment.

1. The bare metal hybrid deployment solution runs on OpenAMP to manage peripherals by partition at a high performance level; however, it delivers poor isolation and flexibility. This solution supports the hybrid deployment of UniProton/Zephyr/RT-Thread and openEuler Embedded Linux.
2. Partitioning-based virtualization is an industrial-grade hardware partition virtualization solution that runs on Jailhouse. It offers superior performance and isolation but inferior flexibility. This solution supports the hybrid deployment of UniProton/Zephyr/FreeRTOS and openEuler Embedded Linux or of OpenHarmony and openEuler Embedded Linux.
3. Real-time virtualization is available as two community hypervisors, ZVM (for real-time VM monitoring) and Rust-Shyper (for Type-I embedded VM monitoring).

## MICA Deployment Framework

The MICA deployment framework is a unified environment that masks the differences between technologies that comprise the embedded elastic virtualization base. The multi-core capability of hardware combines the universal Linux OS and a dedicated real-time operating system (RTOS) to make full use of all OSs.

The MICA deployment framework covers lifecycle management, cross-OS communication, service-oriented framework, and multi-OS infrastructure.

- Lifecycle management provides operations to load, start, suspend, and stop the client OS.
- Cross-OS communication uses a set of communication mechanisms between different OSs based on shared memory.
- Service-oriented framework enables different OSs to provide their own services. For example, Linux provides common file system and network services, and the RTOS provides real-time control and computing.
- Multi-OS infrastructure integrates OSs through a series of mechanisms, covering resource expression and allocation and unified build.

The MICA deployment framework provides the following functions:

- Lifecycle management and cross-OS communication for openEuler Embedded Linux and the RTOS (Zephyr or UniProton) in bare metal mode
- Lifecycle management and cross-OS communication for openEuler Embedded Linux and the RTOS (FreeRTOS or Zephyr) in partitioning-based virtualization mode

## Northbound Ecosystem

- **Northbound software packages**: Over 700 common embedded software packages can be built using openEuler.

- **Soft real-time kernel**: This capability helps respond to soft real-time interrupts within microseconds.
- **DSoftBus**: The distributed soft bus system (DSoftBus) of openEuler Embedded integrates the DSoftBus and point-to-point authentication module of OpenHarmony. It implements interconnection between openEuler-based embedded devices and OpenHarmony-based devices as well as between openEuler-based embedded devices.
- **Embedded containers and edges**: With iSula containers, openEuler and other OS containers can be deployed on embedded devices to simplify application porting and deployment. Embedded container images can be compressed to 5 MB, and can be easily deployed into the OS on another container.

## UniProton

UniProton is an RTOS that features ultra-low latency and flexible MICA deployments. It is suited for industrial control because it supports both microcontroller units and multi-core CPUs. UniProton provides the following capabilities:

- Compatible with processor architectures like Cortex-M, AArch64, x86_64, and riscv64, and supports M4, RK3568, RK3588, x86_64, Hi3093, Raspberry Pi 4B, Kunpeng 920, Ascend 310, and Allwinner D1s.
- Connects with openEuler Embedded Linux on Raspberry Pi 4B, Hi3093, RK3588, and x86_64 devices in bare metal mode.
- Can be debugged using GDB on openEuler Embedded Linux.

## Application Scenarios

openEuler Embedded helps supercharge computing performance in a wide range of industries and fields, including industrial and power control, robotics, aerospace, automobiles, and healthcare.

# 5 Kernel Innovations

openEuler 24.03 LTS SP2 runs on Linux kernel 6.6 and inherits the competitive advantages of community versions and innovative features released in the openEuler community.

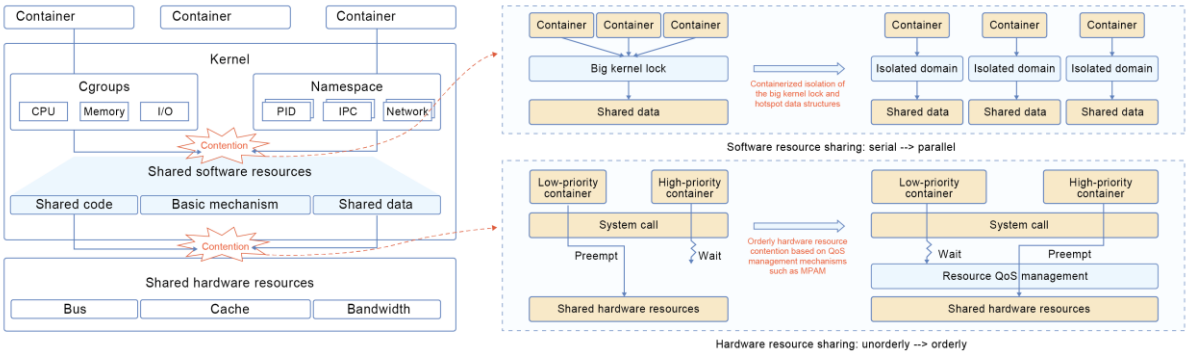
- **Filesystem in USErspace (FUSE) pass-through**: FUSE is widely used in distributed storage and AI applications. In pass-through scenarios, FUSE skips additional processing for read and write I/Os. It only records metadata and forwards the I/O requests to the back-end file system. As a result, FUSE processing turns into the main bottleneck for I/O performance. The FUSE pass-through feature is designed to eliminate the overhead caused by context switches, wakeups, and data copying on the data plane when FUSE directly interfaces with the back-end file system. It allows applications to directly send read and write I/Os to the back-end file system within the kernel. In lab environments, FUSE pass-through has demonstrated notable performance gains. Specifically, fio tests show that read and write performance more than doubles for sizes between 4 KB and 1 MB. FUSE pass-through has also passed fault injection and stability tests, and is available for use as needed.
- **Enhanced Memory System Resource Partitioning and Monitoring (MPAM) features**: An improved QoS feature is introduced to optimize memory bandwidth and L3 cache control. In hybrid deployment scenarios, shared resources can be allocated based on the upper limit, lower limit, or priority-based policy. The new I/O QoS management feature collaborates with the system memory management unit (SMMU) to isolate I/O bandwidth traffic across hardware peripherals and heterogeneous accelerators. It supports monitoring by iommu_group, providing a new approach to I/O QoS management in heterogeneous environments. In addition, the L2 cache isolation feature enables monitoring of L2C usage

and bandwidth traffic, offering core-level optimization and performance analysis in hybrid deployment scenarios. These MPAM features deliver significant performance improvements in test scenarios. In hybrid deployments, the interference rate of SPECjbb as an online service drops from 25.5% to below 5%.

# 6 Cloud Base

## High-Density Many-Core Container Isolation

Server chips have evolved from multi-core to many-core architectures (typically exceeding 256 cores), posing new challenges to OSs. To boost rack-level computing density and reduce data center TCO, many-core servers have become the mainstream in the Internet industry. As cloud technologies and service scales advance, containerized deployment has also become the dominant model. Against this backdrop, serialization and synchronization overheads hinder system scalability, while interference and low resource utilization become increasingly prominent. These scalability issues in container deployments arise from contention for shared hardware and software resources.




## Feature Description

Lightweight virtualization is used to partition resources by NUMA domain and enforce container-level resource isolation within each domain. This approach minimizes performance interference caused by hardware and software resource contention and enhances the container deployment scalability.

- **Lightweight virtualization**: Virtual device interrupt offloading allows VirtIO device interrupts to be handled by hardware, reducing storage virtualization overhead. Poll Mode Driver (PMD) queue load balancing spreads VirtQueues from a single reactor to multiple reactors, eliminating CPU bottlenecks.
- **CPU scheduling by domain**: CPUs are divided into domains by cluster for container deployment. Each container operates within an independent scheduling domain. This design isolates interference between containers, reduces cross-cluster cache synchronizations, and eases contention for hardware resources like cache and NUMA memory. It improves performance by more than 10% in high-concurrency Redis scenarios.
- **Interference isolation in file system block allocation**: Optimizations to the group lock and s_md_lock in the EXT4 block allocation and release processes enhance the scalability of EXT4 block allocation. When the target block group is occupied, allocation can switch to an idle block group to reduce CPU overhead caused by multiple containers competing for the same group. Leveraging multiple EXT4 block groups helps ease group lock contention. Apart from that, the global target of the streaming allocation is split to inodes, so that the contention for the global lock s_md_lock is alleviated and the file data is more aggregated. In a 64-

container concurrency scenario, the OPS increases by over 5 times in mixed block allocation and release workloads and by over 10 times in single-block allocation workloads.

- **TCP hash interference isolation**: In high-concurrency scenarios, lock contention in tcp_hashinfo bash and ehash and frequent ehash calculations lead to reduced bandwidth and increased latency. The spin lock of tcp_hashinfo bash and ehash can be replaced with read-copy update (RCU), and the ehash calculation method can be changed to lport increment. These changes reduce the query time and calculations and reduce the lock contention in the TCP connection hash.
- **Enhanced control group (cgroup) isolation**: Original atomic operations are replaced with percpu counters to avoid parent node contention across namespaces and eliminate rlimit count interference between containers. This mechanism addresses the linearity issue in the **will-it-scale/signal1** test case and triples concurrent throughput performance in a 64-container deployment. Memory cgroups are released in batches to avoid contention for the same parent node's counter caused by frequent small memory releases, enhancing memory count scalability. In the **tlb-flush2** test case, this improves throughput by 1.5 times with 64 containers. Leveraging eBPF's programmable kernel capabilities, a host information isolation and filtering approach is provided to present container-specific resource views. Compared with the peer LXCFS solution, this openEuler solution avoids the overhead of switching between the kernel mode and user mode, and eliminates the performance and reliability bottlenecks associated with the LXCFS process. It doubles the resource view throughput in a single container and achieves a 10-fold increase in a 64-container deployment.
- **Interference monitoring**: Interference falls into three categories by result: instruction execution failure, instruction slowdown, and increased instruction execution. Interference is monitored from the kernel perspective, with statistics collected on each typical category during runtime. The system supports online monitoring of schedule latency, throttling, softirq, hardirq, spin lock, mutual exclusion (mutex), and simultaneous multi-threading (SMT) interference while incurring less than 5% performance overhead.
- **Kunpeng memory and cache QoS control**: The memory bandwidth traffic and cache usage at each level can be configured based on the upper limit, lower limit, or priority-based policy. Each thread is assigned a specific isolation policy to suit specific service requirements. The usage of shared resources is monitored in real time at both service and thread levels, and reported to the control policy to enable feedback-driven control. In addition, the MPAM feature and the SMMU combine to enhance peripherals' I/O QoS. They support bandwidth isolation for peripherals and heterogeneous accelerators and allow for resource monitoring at the device level.

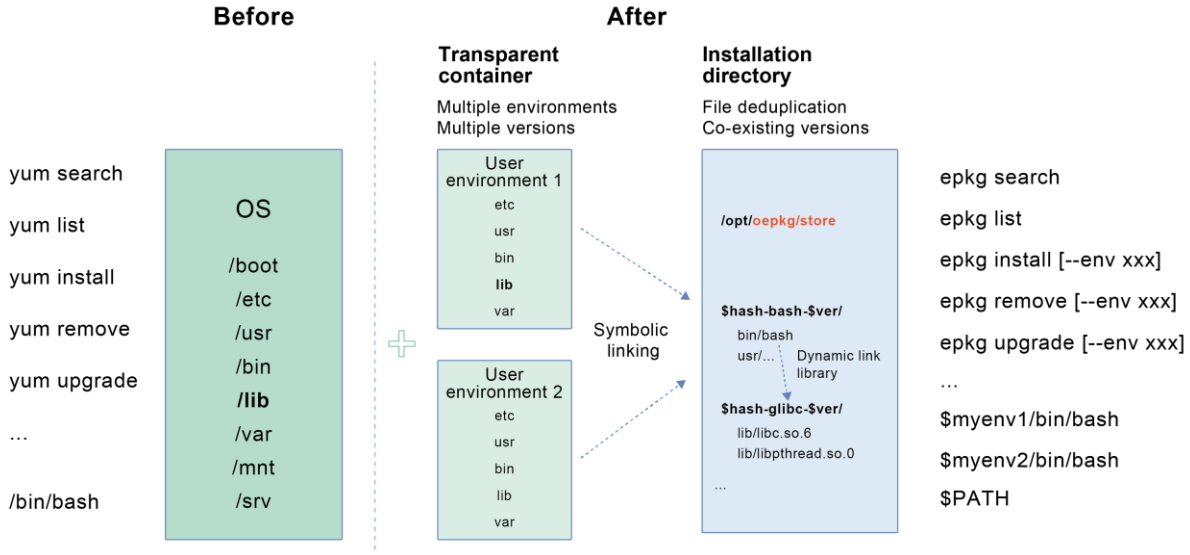
## Application Scenarios

In a many-core server environment, service containers are deployed in a high-density configuration. The openEuler solution minimizes interference between containers, increases deployment density, and enhances resource utilization.

# 7 Enhanced Features

## epkg

epkg is a new software package manager that is designed to install and manage non-service software packages. It solves version compatibility issues so that users can install and run software of different versions on the same OS by using simple commands to create, enable, and switch between environments.




## Feature Description

**Version compatibility**: enables multiple versions of a software package to run on the same node.

**Environment management**: allows users to create, enable, and switch between environments. Users can use channels of different environments to use different software package versions. When an environment is switched to another, the software package version is also changed.

**Installation by common users**: allows common users to install software packages, create environments, and manage their environment images, reducing security risks associated with software package installation.

## Application Scenarios

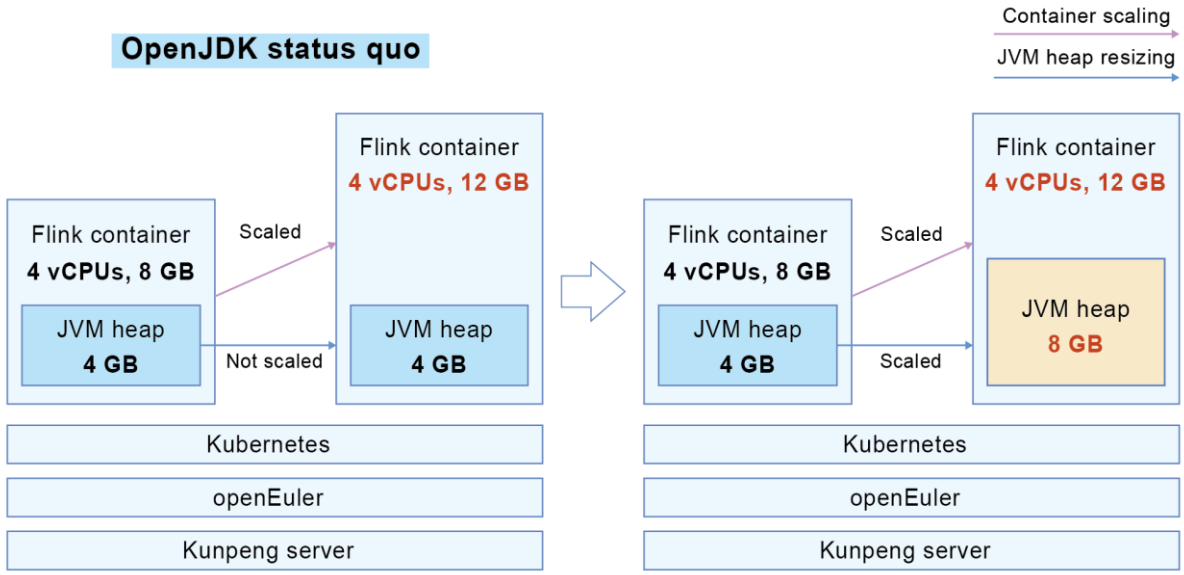
epkg solves compatibility issues in installing multiple versions of the same software package. Users can switch between environments to use different software package versions.

For details, refer to the epkg User Guide.

# Heap Resizing by BiSheng JDK 8

## Feature Description

In modern containerized deployments, most users' container environments support resource scale-up. However, OpenJDK 8 has a significant limitation: its maximum heap size can only be configured at startup. This means it does not support online resizing, preventing Java applications from immediately using additional memory made available after a container scales up. Applications currently require a restart to reset their maximum heap. To address this limitation, BiSheng JDK 8 introduces online heap memory resizing for the Garbage-First garbage collector (G1GC). This allows users to dynamically update the Java heap memory limit while an application is running, eliminating the need for a JVM restart.




## Application Scenarios

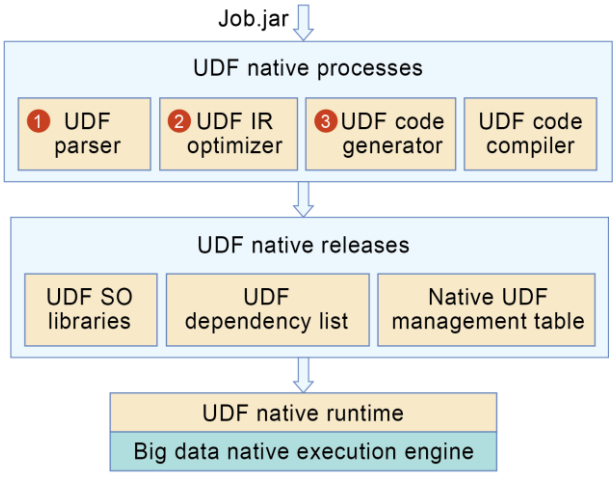
This capability is crucial for Internet and other container-based deployments that require Java application heap memory to resize online in response to container resource scale-up.

# UDF Automatic Native Framework

## Feature Description

The UDF automatic native framework addresses the inefficient JVM execution often seen in open source big data systems. It automatically converts Java User-Defined Functions (UDFs) into C/C++ Native UDFs, significantly boosting big data processing performance through efficient memory management and hardware affinity. Essentially, the framework implements a seamless, automatic Java UDF native acceleration mechanism. It comprises the UDF parser, UDF IR optimizer, UDF code generator, and UDF code compiler modules.

The UDF parser automatically converts the bytecode of a service JAR package into Intermediate Representation (IR) code and extracts UDF code by identifying its specific features. The UDF IR optimizer optimizes the UDF IR from dimensions such as automatic memory object management and hardware-affinity acceleration. The UDF code generator translates the optimized UDF IR into native code. The UDF code compiler compiles the UDF native code into native binaries online. Finally, these UDF native binaries are deployed to big data execution nodes. The native execution engine of the big data system dynamically loads and executes the native binaries. This improves the big data processing performance.




## Application Scenarios

The UDF automatic native framework is designed to seamlessly integrate with the Flink big data native execution engine. By leveraging a Flink DataStream native base library, it achieves automatic native acceleration for Flink DataStream UDFs, all without requiring any user intervention.

## ANNC

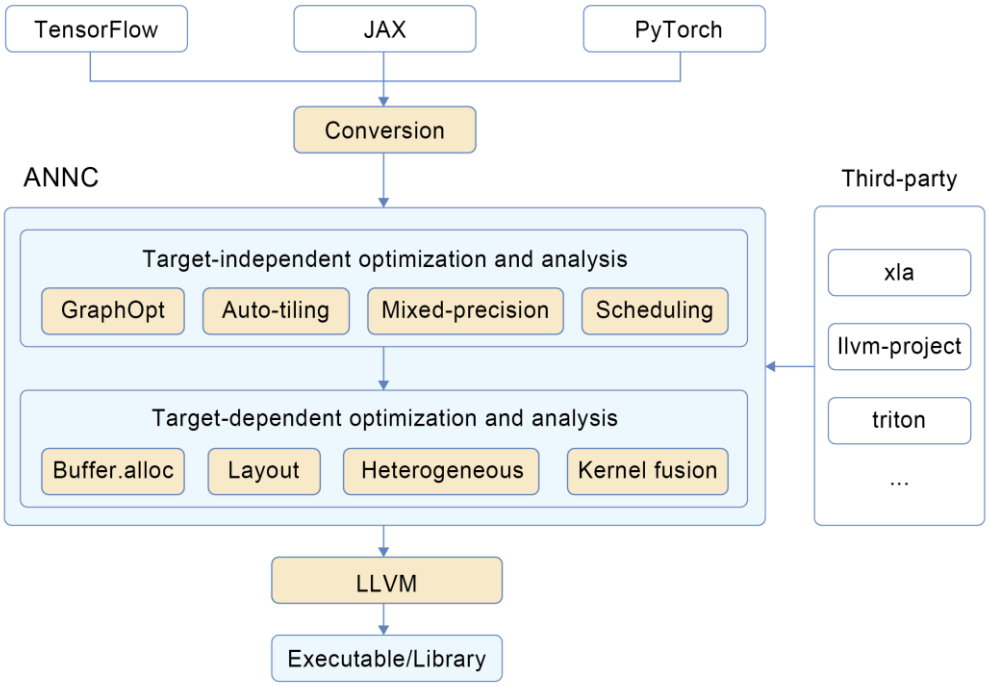
Accelerated Neural Network Compiler (ANNC) is an AI compiler designed for accelerating neural network computations. It focuses on computation graph optimization, high-performance fused operator generation, and efficient code generation and optimization to boost the inference performance of models like recommendation systems and large language models (LLMs). It can integrate with mainstream open source inference frameworks and various hardware back-ends to enhance software extensibility.

## Feature Description

Computation graph optimization refines the neural network's computational flow. From an algorithmic perspective, it reduces redundant operations, performs mixed-precision rewriting, and automatically schedules subgraphs to lower the computational load and improve cache utilization. From a hardware architecture perspective, it optimizes the tensor data layout, operator fusion and conversion, and subgraph partitioning and scheduling to further lower the load and fully utilize hardware resources.

Generating and integrating a high-performance fused operator library comprises three parts: front-end computation graph pattern recognition and conversion, high-performance operator library query and integration, and automated operator library generation. At the assembly instruction level, it reduces memory access and accelerate parallel computations through optimization techniques like data prefetching, model parallelism, and new instruction sets.

ANNC aims to accelerate AI inference and reduce power consumption through graph compilation optimization and high-performance operator generation and integration, thereby improving inference efficiency per unit cost. In addition, its software compatibility and ease-of-use design reduce operational costs and environmental impact.




## Application Scenarios

ANNC now focuses on graph compilation optimization and operator library selection and invocation. It yields significant benefits for coarse- and fine-ranking models in mainstream search and recommendation systems. Graph compilation optimization achieves even better results for complex embedding layer networks that handle intricate feature processing.

Moreover, ANNC has also laid the groundwork for performance optimization in future scenarios, such as LLMs. By integrating with LLM inference frameworks and combining existing graph-operator fusion and memory layout optimization techniques with core performance optimization methods like GEMM, it aims to reduce inference latency and increase inference throughput.

# Enhanced oeDeploy

oeDeploy is a lightweight software deployment tool that accelerates environment setup across single-node and distributed systems with unmatched efficiency.

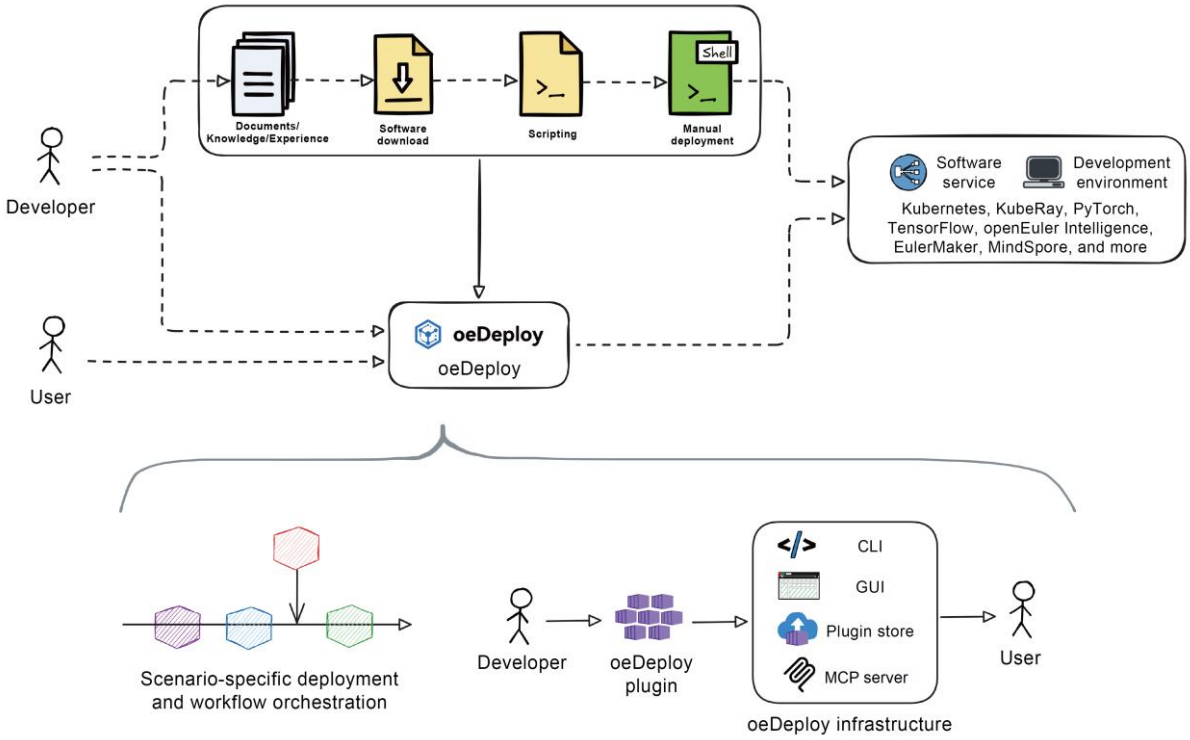
## Feature Description

**Multi-scenario support and quick software deployment**: oeDeploy facilitates quick deployment for both single-node applications and clustered software environments. It now includes quick deployment capabilities for Kubernetes environments with multiple master nodes. It also extends support for community toolchains like openEuler Intelligence and DevKit Pipeline, as well as popular Retrieval Augmented Generation (RAG) software such as RAGFlow, AnythingLLM, and Dify.

**Flexible plugin management and excellent deployment experience**: oeDeploy provides an extensible plugin architecture for flexible management of diverse deployment capabilities, empowering developers to quickly release custom deployment plugins. It now supports plugin source management, enabling one-click plugin updates and one-click plugin initialization. While

oeDeploy currently offers a streamlined CLI, a GUI and plugin store will soon launch, promising an even more efficient software deployment experience with less code.

**Efficient deployment and intelligent development**: oeDeploy introduces the MCP service, offering an out-of-the-box experience within DevStation. It leverage LLM inference to deploy software with natural language, boosting deployment efficiency by 2x. It can also convert user documents into executable oeDeploy plugins, increasing development efficiency by 5x.




## Application Scenarios

ISVs and development teams can adopt oeDeploy as a standardized solution for software product delivery. Its CLI tools and plugin framework minimize development overhead while ensuring smooth delivery, reducing customer onboarding efforts, and enhancing satisfaction.

For developers and maintenance personnel, oeDeploy enables instant setup of complex environments, deploying mainstream AI training and inference frameworks in just minutes. This significantly streamlines software development and eliminates tedious configuration work. Developers can also extend oeDeploy by creating and sharing custom deployment templates, democratizing quick deployment for broader user communities. By leveraging foundation models and MCP capabilities, oeDeploy makes deployment more efficient and development more intelligent.

## Enhanced DevStation

DevStation is an intelligent Live CD developer workstation built on openEuler, designed for geeks and innovators. It provides an out-of-the-box, efficient, and secure development environment that streamlines the entire workflow from deployment and coding to compilation, building, and releasing. By integrating a one-click runtime environment with a full-stack development toolchain, it enables a seamless transition from system boot to code execution. The new MCP AI engine

allows for quick invocation of community toolchains, offering a significant leap in efficiency from infrastructure setup to application development, all without complex installation.

## Feature Description

**Developer-friendly integrated environment**: Pre-installed with a wide range of development tools and IDEs like VSCodium, this distribution supports multiple programming languages to meet the needs of front-end, back-end, and full-stack developers.

**Native community tool ecosystem**: New tools like oeDeploy (a one-click deployment tool), epkg (an extended package manager), DevKit (a development toolchain), and openEuler Intelligence (an intelligent Q&A system) provide full-lifecycle support from environment configuration to code deployment. oeDevPlugin and oeGitExt are VSCodium plugins designed for the openEuler community. They provide visual management for issues and pull requests (PRs), facilitating code repository cloning, PR submission, and real-time task status synchronization. openEuler Intelligence supports natural language for generating code snippets, creating API references, and explaining Linux commands.

**GUI-based programming environment**: DevStation integrates graphical programming tools to streamline coding for beginners while offering powerful visual programming capabilities for veterans. It also comes pre-installed with productivity tools like Thunderbird.

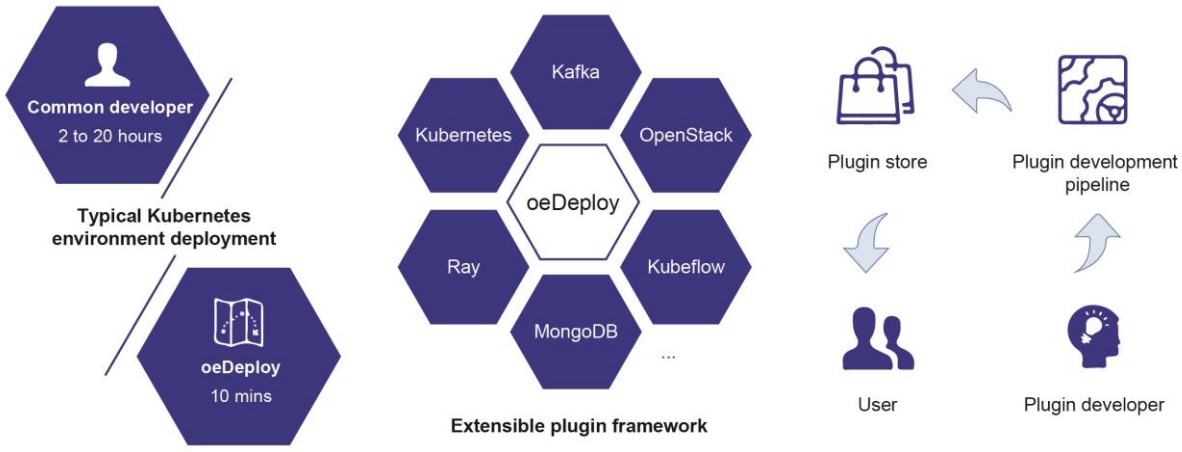
**MCP-based intelligent application ecosystem**: DevStation deeply integrates the Model Context Protocol (MCP) framework to build a complete intelligent toolchain ecosystem. It includes pre-installed MCP servers like oeGitExt and rpm-builder, which provide capabilities for community task management and RPM packaging. It intelligently wraps conventional development tools like Git and RPM builders using the MCP protocol, offering a natural language interaction interface.

**Enhanced system deployment and compatibility**: DevStation offers extensive hardware support, especially seamless compatibility with mainstream laptop and PC hardware (such as touchpads, Wi-Fi, and Bluetooth), and a restructured kernel build script (**kernel-extra-modules**) to ensure bare metal deployment experience. It also supports flexible deployment options, including Live CD (one-click run without installation), bare metal installation, and VM deployment.

## Application Scenarios

**Multi-language development**: DevStation is ideal for developers working on multi-language projects, such as Python, JavaScript, Java, and C++. With various pre-installed compilers, interpreters, and build tools, it eliminates the need for manual configuration.

**Quick installation and deployment**: DevStation integrates oeDeploy to deploy distributed software such as Kubeflow and Kubernetes within minutes. oeDeploy provides a unified plugin framework and atomic deployment capabilities, allowing developers to quickly release custom installation and deployment plugins.




**Hardware compatibility and bare metal testing**: For testers and developers focused on southbound compatibility, DevStation ensures robust hardware support for mainstream laptops and servers, and allows bare metal deployment for driver compatibility testing.

**Improved developer efficiency**: The MCP RPM-builder toolchain improves MCP usability by supporting automated packaging and releasing of RPM packages to the community. This ensures that one-click MCP server installation is always available. It helps build a complete MCP intelligent application ecosystem repository that covers scenarios like deployment, testing, and performance tuning, including querying assigned community issues, creating PRs to submit code changes, and automating build and verification via CI/CD.

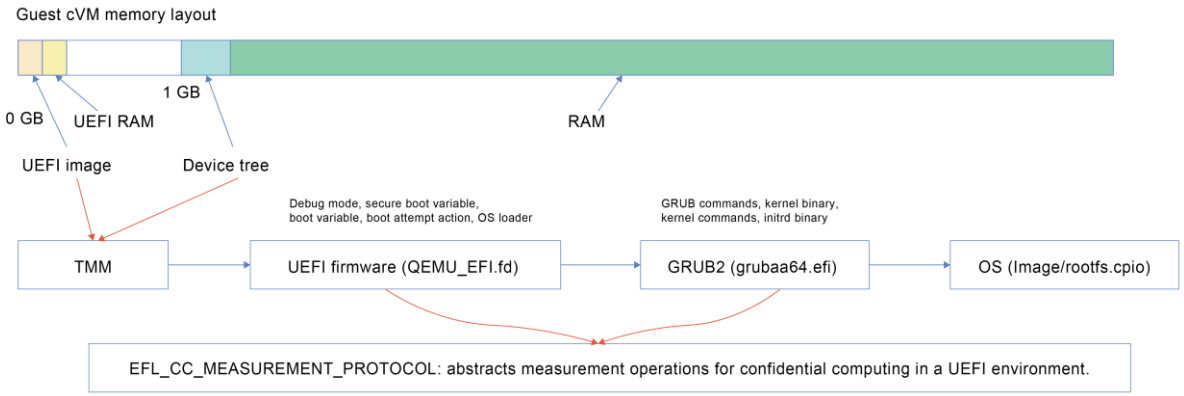
# Enhanced virtCCA

## Feature Description

The current virtCCA architecture has this constraint: it only supports a boot mode where the kernel and rootfs are mounted separately. However, in mainstream cloud platforms, VMs typically rely on a GRUB bootloader. This requires integrating the Unified Extensible Firmware Interface (UEFI) firmware (like EDK2), kernel, and initial RAM file system (initramfs) into a single image, such as a QCOW2 file. Enhanced virtCCA addresses this by providing the following functions:

- Single image encapsulation
  - **Unified boot stack**: virtCCA integrates the EDK2 firmware, GRUB bootloader, kernel, and initramfs into a QCOW2 image, creating a complete boot stack.
  - **Streamlined boot process**: GRUB uses a configuration file (**grub.cfg**) to locate the kernel path, which requires the kernel and initramfs to reside on the same file system, for example, EXT4 or XFS.
- Secure boot chain
  - **Secure boot**: EDK2 verifies the digital signatures of GRUB and the kernel, ensuring that the boot components have not been tampered with.
  - **Hardware resource collaboration**: virtCCA leverages UEFI runtime services to enumerate hardware devices, providing a virtualized resource pool for hypervisors like KVM.
- Cloud native optimization

  virtCCA supports snapshot cloning and dynamic rootfs expansion (depending on cloud-init in initramfs).




## Application Scenarios

The adoption of UEFI as a boot mode in cloud environments is a core technology for modern virtualization. virtCCA's new UEFI support expands its use cases for confidential VMs (cVMs):

- Fast instance boot and auto scaling

  UEFI uses parallel hardware initialization (such as simultaneous detection of CPUs, memory, and storage devices) to significantly shorten the boot time.

- Large-capacity drive support

  Be leveraging the GUID Partition Table (GPT), UEFI breaks the traditional MBR limit of 2 TB. This allows virtCCA to support cloud drives of 100 TB or more (like Alibaba Cloud's ESSDs), which is essential for big data storage (such as HDFS) and AI training.

- Automated O&M and batch deployment

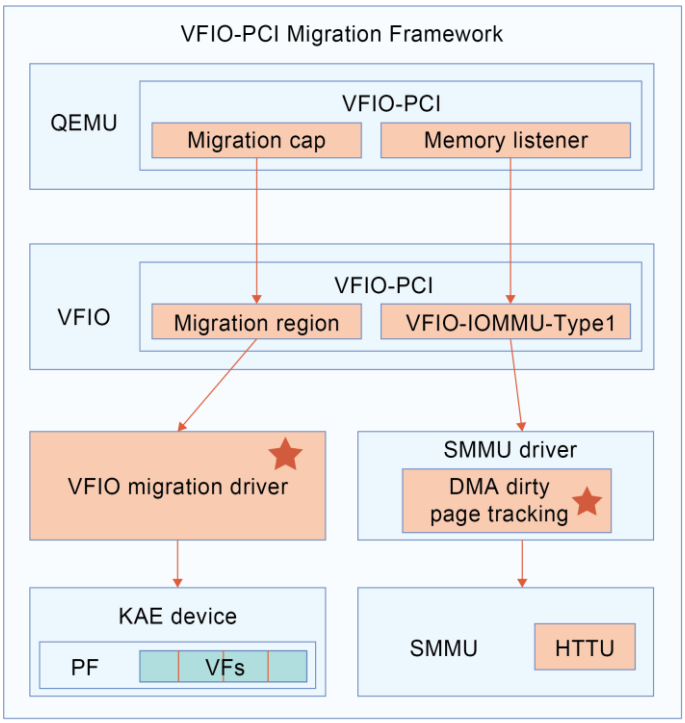
  UEFI-compatible images provided by cloud service providers streamline user deployment by enabling GPT partitioning by default.

# vKAE Passthrough Live Migration

## Feature Description

The Kunpeng Accelerator Engine (KAE) is a hardware acceleration solution based on the new Kunpeng 920 processor model, featuring HPRE, SEC, and ZIP components for encryption, decryption, compression, and decompression. This allows KAE to significantly reduce processor overhead and boost efficiency. KAE passthrough live migration addresses the scenario where VMs are configured with KAE passthrough devices, offering enhanced operational flexibility and continuous service availability.

SMMU dirty page tracking is a key technology for efficient and reliable live migration of passthrough devices. In the Arm architecture, a purely software-based approach to dirty page tracking incurs significant performance overhead. Hardware Translation Table Update (HTTU) solves this by allowing the hardware to automatically update the SMMU page table status. During a write operation, the write permission bit of the corresponding page table entry is automatically set. During a live migration, the write permission bit of the page table is scanned to collect statistics on dirty pages.




## Application Scenarios

This feature empowers live migration for VMs using KAE passthrough devices, making it ideal for fields with high requirements for data security and processing performance, such as finance, cloud computing, and big data processing. Ultimately, it enhances business continuity and operational stability.

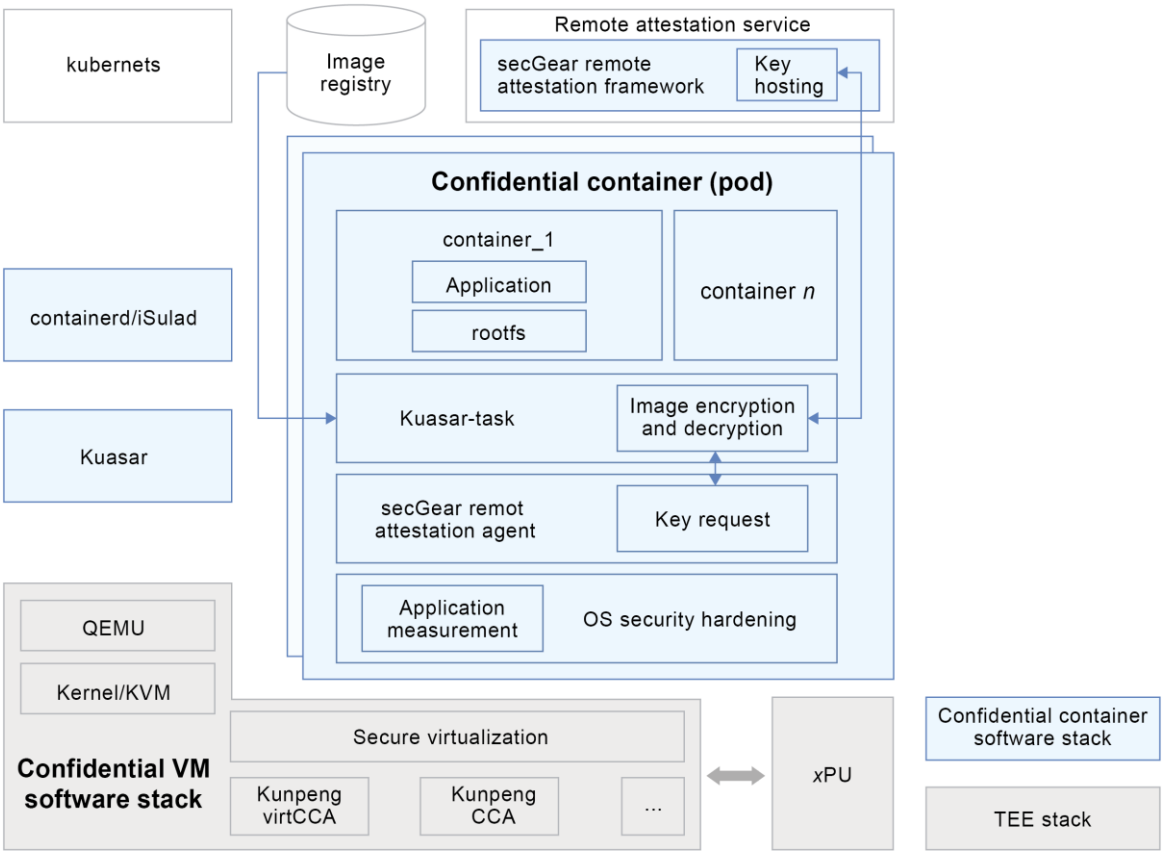
# Kuasar Confidential Container

## Feature Description

Kuasar has extended its capabilities to include confidential container support while maintaining its existing secure container functionality. This support can be enabled through iSulad runtime configuration.

Key functions include:

- Native integration with the iSulad container engine preserves Kubernetes ecosystem compatibility.
- Hardware-level protection via Kunpeng virtCCA technology ensures confidential workloads are deployed in trusted environments.
- The secGear remote attestation framework, which complies with the remote attestation procedures (RATS) (RFC9334), allows containers running in a confidential computing environment to prove their trustworthiness to external trusted services.
- Container images can be pulled and decrypted in confidential containers to protect their confidentiality and integrity.




## Application Scenarios

Kuasar addresses data security concerns while seamlessly integrating with cloud native ecosystems. It benefits confidential applications from cloud native advantages including high availability, auto scaling, and rapid delivery. The solution finds broad application in confidential computing scenarios spanning AI security, trusted data circulation, and privacy protection.

# Global Trust Authority for Remote Attestation

## Feature Description

The GTA remote attestation component adopts the client-server model, carrying remote attestation of the Trusted Platform Module (TPM) and vTPM.

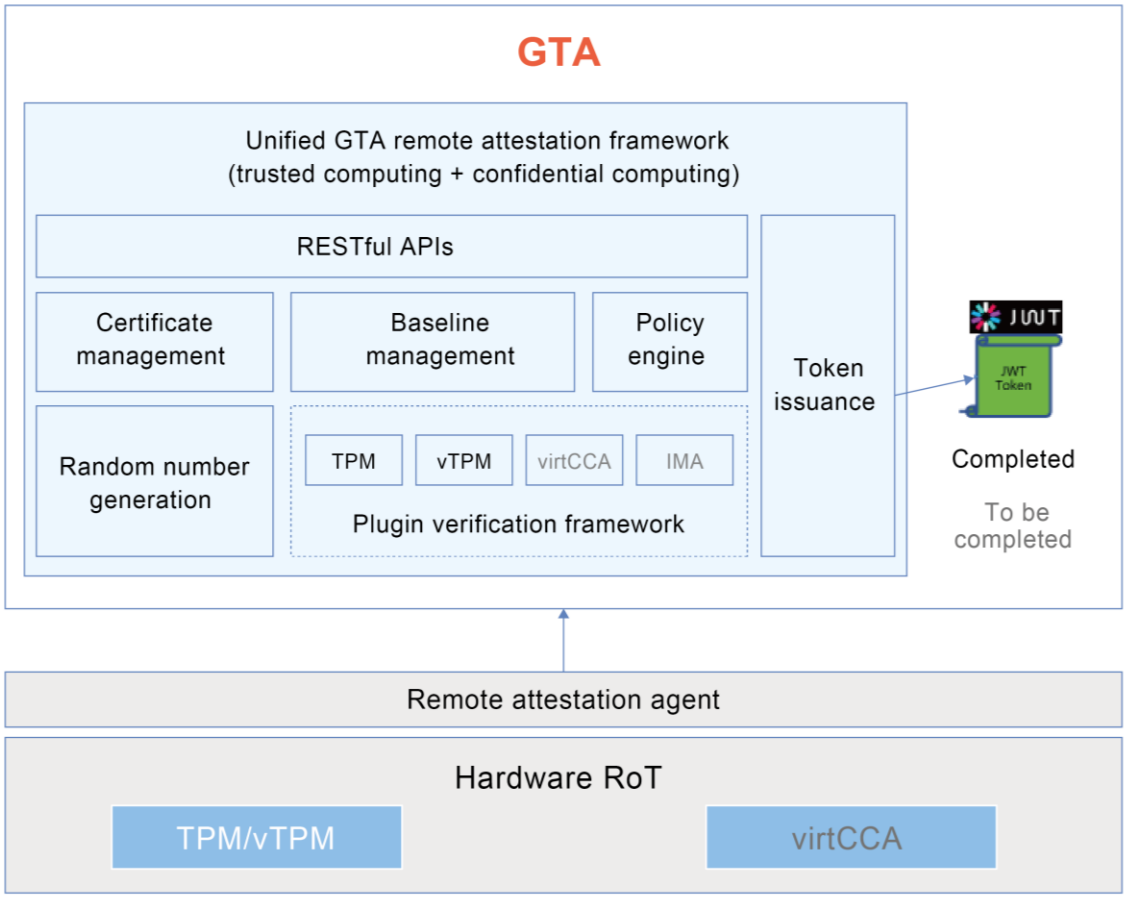
- The server provides the remote attestation service framework, which is compatible with trusted computing and confidential computing. It supports the addition, deletion, modification, and query of certificates and policies, quote verification, random number generation, and JWT token generation.
- The client collects local TPM evidence and interacts with the server to verify quotes.

This component provides various capabilities in terms of security and usability.

- As for security, GTA provides differentiated security competitiveness such as database integrity protection, data link encryption, anti-replay, SQL injection prevention, user isolation, and key rotation.

- Regarding usability, the passport and background-check models are available. The client supports multiple verification modes, such as scheduled reporting and challenge response. Both the client and server can be deployed using RPM packages and within Docker containers.

  In later versions, GTA will offer virtCCA confidential computing verification.

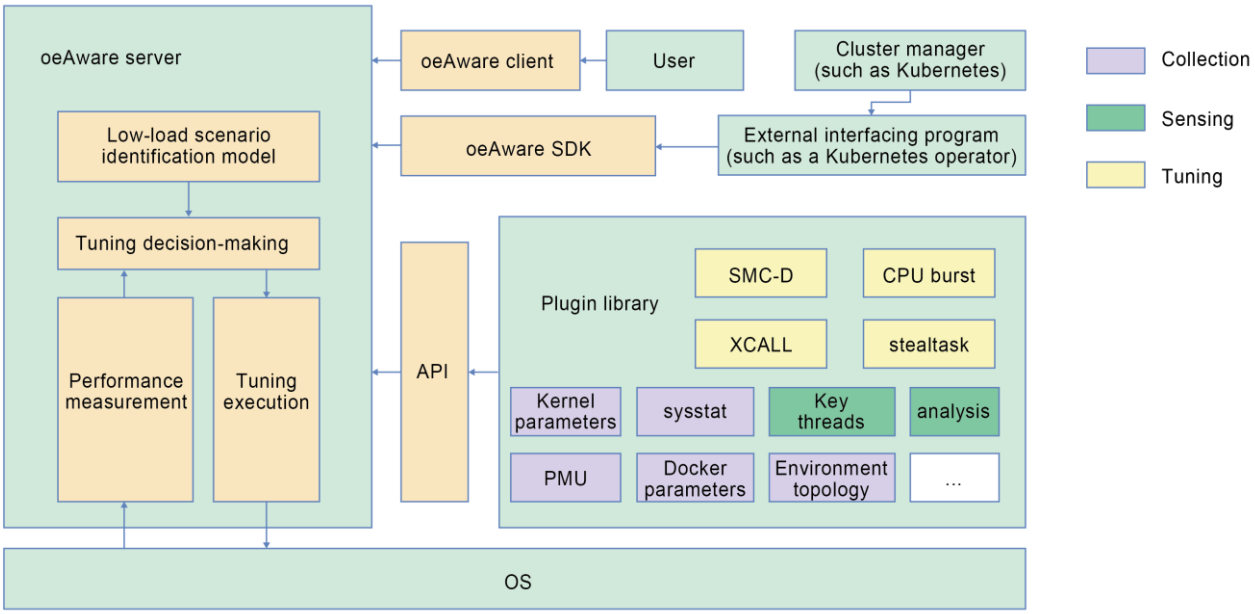



## Application Scenarios

Remote attestation is a prerequisite for enabling confidential computing and trusted computing. Subsequent computations are allowed only when the operating environment is strictly proven to be secure and trustworthy in the cryptographic sense. Remote attestation should be included as a core component of all end-to-end solutions involving confidential computing. If the operating environment is untrusted, the subsequent tasks must be stopped. This service is widely used in AI model protection, user privacy protection, and key management.

# Enhanced oeAware

oeAware is a framework that provides low-load collection, sensing, and tuning upon detecting defined system behaviors on openEuler. The framework divides the tuning process into three layers: collection, sensing, and tuning. Each layer is associated through subscription and developed as plugins, overcoming the limitations of traditional tuning techniques that run independently and are statically enabled or disabled.




## Feature Description

Every oeAware plugin is a dynamic library that utilizes oeAware interfaces. The plugins comprise multiple instances that each contains several topics and deliver collection or sensing results to other plugins or external applications for tuning and analysis purposes.

- The SDK enables subscription to plugin topics, with a callback function handling data from oeAware. This allows external applications to create tailored functionalities, such as cross-node information collection or local node analysis.
- The performance monitoring unit (PMU) information collection plugin gathers performance records from the system PMU.
- The Docker information collection plugin retrieves specific parameter details about Docker containers in the environment.
- The system information collection plugin captures kernel parameters, thread details, and resource information (CPUs, memory, I/Os, network) from the current environment.
- The thread sensing plugin monitors key information about threads.
- The evaluation plugin examines system NUMA and network information during service operations, suggesting optimal tuning methods.
- The system tuning plugins comprise stealtask for enhanced CPU tuning, smc_tune (SMC-D) which leverages shared memory communication in the kernel space to boost network throughput and reduce latency, xcall_tune (XCALL) which bypasses non-essential code paths to minimize system call processing overhead.
- The Docker tuning plugin addresses CPU performance issues during sudden load spikes by utilizing the CPU burst feature.

### Constraints

- **smc_tune**: SMC acceleration must be enabled before the server-client connection is established. This plugin is most effective in scenarios with numerous persistent connections.
- **Docker tuning**: This plugin is not compatible with Kubernetes containers.
- **xcall_tune**: The **FAST_SYSCALL** kernel configuration option must be activated.

## Application Scenarios

stealtask is ideal for scenarios aiming to boost CPU utilization, such as in Doris. This tuning instance effectively increases CPU utilization and prevents idle CPU cycles.

xcall_tune is designed for applications with substantial system call overhead. It offers code paths that bypass non-critical processes, optimizing system call handling and reducing overhead. However, this approach may compromise some maintenance and security capabilities.

smc_tune excels in environments demanding high throughput and low latency, including HPC, big data processing, and cloud platforms. By leveraging DMA, smc_tune significantly reduces CPU load and accelerates interactive workloads.

CPU burst is tailored for high-load container environments like Doris, addressing performance bottlenecks caused by CPU constraints.

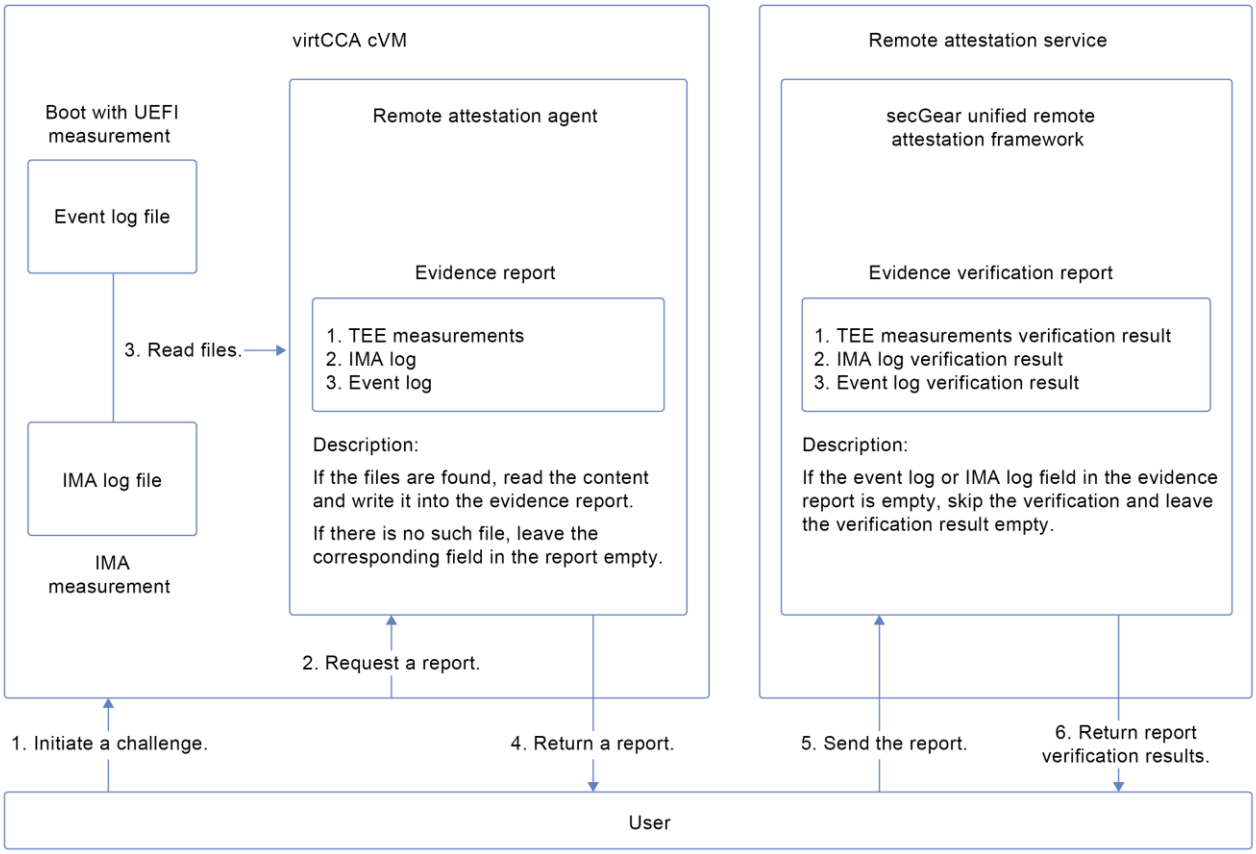
# Enhanced secGear

The secGear unified remote attestation framework addresses the key components related to remote attestation in confidential computing, abstracting away the differences between different Trusted Execution Environments (TEEs). It provides two components: attestation agent and attestation service. The agent is integrated by users to obtain attestation reports and connect to the attestation service. The service can be deployed independently and supports the verification of iTrustee and virtCCA remote attestation reports. secGear now supports remote attestation of virtCCA cVMs booted with Unified Extensible Firmware Interface (UEFI) measurement. In addition, the custom virtCCA Integrity Measurement Architecture (IMA) register is added to prevent conflicts caused by enabling both UEFI and IMA measurements.

## Feature Description

During boot with UEFI measurement, the measurement operation is recorded in an ACPI table: Confidential Computing Event Log (CCEL). Based on the CCEL, secGear implements remote attestation for virtCCA cVMs. secGear remote attestation verifies the integrity and trustworthiness of the UEFI boot process by processing the event log file, and provides evidence for subsequent remote attestation procedures.

When this feature is used, the remote attestation agent obtains the event log file content on a virtCCA cVM. If the event log file is found, the agent encapsulates the file content and other necessary information into a report and sends the report to the remote attestation service for verification. The service then returns a report containing the event log verification result. If there is no event log file on the cVM, the procedure is the same as that in direct boot mode. The agent encapsulates only necessary information into a report and sends the report to the service for verification. The service returns a report that does not contain the event log verification result.




secGear remote attestation process

After IMA measurement is enabled for the virtCCA cVM, the **pcr** parameter can be customized during IMA policy configuration to specify a virtCCA register. If both IMA and UEFI measurements are enabled, set **pcr=4** in the IMA policy to ensure IMA measurement uses the last virtCCA register, thereby preventing measurement extension conflicts.

## Application Scenarios

In scenarios like finance and AI, where confidential computing is used to protect the security of privacy data during runtime, remote attestation is a technical means to verify the legitimacy of the confidential computing environment and applications. secGear provides components that are easy to integrate and deploy, helping users quickly enable confidential computing remote attestation capabilities.

# Enhanced GCC for openEuler CFGO

The continuous growth in code volume has made front-end bound execution a common issue in processors, which impacts program performance. Feedback-directed optimization techniques in compilers can effectively solve this issue.

Continuous Feature Guided Optimization (CFGO) in GCC for openEuler refers to continuous feedback-directed optimization for multimodal files (source code and binaries) and the full lifecycle (compilation, linking, post-linking, runtime, OS, and libraries). The following techniques are included:

- **Code layout optimization**: Techniques such as basic block reordering, function rearrangement, and hot/cold separation are used to optimize the binary layout of the target program, improving I-cache and I-TLB hit rates.

- **Advanced compiler optimization**: Techniques such as inlining, loop unrolling, vectorization, and indirect calls enable the compiler to make more accurate optimization decisions.

## Feature Description

CFGO comprises CFGO-PGO, CFGO-CSPGO, and CFGO-BOLT. Enabling these sub-features in sequence helps mitigate front-end bound execution and improve program runtime performance. To further enhance the optimization, you are advised to add the **-flto=auto** compilation option during CFGO-PGO and CFGO-CSPGO processes.

- **CFGO-PGO**

  Unlike conventional profile-guided optimization (PGO), CFGO-PGO uses AI for Compiler (AI4C) to enhance certain optimizations, including inlining, constant propagation, and devirtualization, to further improve performance.

- **CFGO-CSPGO**

  The profile in conventional PGO is context-insensitive, which may result in suboptimal optimization. By adding an additional CFGO-CSPGO instrumentation phase after PGO, runtime information from the inlined program is collected. This provides more accurate execution data for compiler optimizations such as code layout and register optimizations, leading to enhanced performance.

- **CFGO-BOLT**

  CFGO-BOLT adds optimizations such as software instrumentation for the AArch64 architecture and inlining optimization on top of the baseline version, driving further performance gains.

## Application Scenarios

CFGO has good versatility and is suitable for C/C++ applications, such as databases and distributed storage, where the overall system performance bottleneck lies in CPU front-end bound execution. It can typically achieve a performance improvement of 5% to 10%.

# New Hygon Secure Processor Models

## Feature Description

The Hygon CPU contains two types of cryptographic coprocessors (CCPs): Platform Secure Processor (PSP-CCP) and Non-Transparent Bridge (NTB-CCP).

PSP-CCP provides Hygon secure processors with built-in functions such as key generation, secure boot, trusted computing, and CSV, and supports cryptographic operations in modules such as the Trusted Key Management Module (TKM).

NTB-CCP is used by C86 general-purpose processor cores to support compute-intensive cryptographic operations.

In openEuler 24.03 LTS SP2, the vendor and device ID of each PSP-CCP and NTB-CCP can be identified to provide extensive hardware support for the system.

## Application Scenarios

Hygon CCPs lay a cryptographic computing foundation for Hygon security functions, and can be used in all scenarios where the functions are applied. PSP-CCP serves as a hardware backbone for Hygon's trusted computing and confidential computing technologies. NTB-CCP provides underlying computing capabilities for cryptographic libraries in the OS.

# Hygon Trusted Computing

## Feature Description

The Hygon trusted computing kernel driver calls command interfaces provided by the kernel CCP module. During initialization, the CCP module's cryptographic virtualization check is unrelated to the trusted computing functionality. This feature optimizes the kernel CCP module to decouple the trusted computing functionality from cryptographic virtualization, without affecting existing code. This improves the robustness of the trusted computing functionality.

## Application Scenarios

This feature makes Hygon trusted computing more independent. It is mainly used for Hygon's trusted computing technologies, including the TPM, Trusted Cryptography Module (TCM), Trusted Platform Control Module (TPCM), Trusted Dynamic Measuring (TDM), and Trusted Secure Boot (TSB).

# Trusted Key Management

In addition to efficient cryptographic computing capabilities, cryptographic applications need to provide secure key management, because key security is the basis of other security functions. Many applications use coarse key management methods, and some even store keys in plaintext in the file system, posing risks to key security. There is an urgent need for secure and easy-to-use key management methods.

Traditional key management solutions use an independent cryptographic card connecting to the mainboard through an external interface like PCIe and to the CPU through the bus. This design has several drawbacks: it raises hardware costs, complicates mainboard design, and increases the attack surface, leaving the system vulnerable to physical attacks on the bus. To address these drawbacks, the Trusted Key Management Module (TKM), as one of Hygon's intrinsic cryptographic technologies, is implemented within the Hygon CPU using a built-in secure processor to support and expand key management.

## Feature Description

This feature provides TKM virtualization and performance optimization.

The TKM virtualization technique can virtualize multiple vTKM instances from the TKM on a physical host. The following functions are available:

- vTKMs are used in VMs. A vTKM provides the same key management and cryptographic computing capabilities as the TKM on the host.
- vTKM instances are isolated from each other. Each vTKM instance represents an independent key space.
- Each VM can exclusively occupy one vTKM instance and use key resources that cannot be accessed by other VMs. Multiple VMs can also share the same vTKM instance and key space.

Optimizations have been made for the kernel to send vTKM instances to the PSP hardware:

- The kernel PSP driver can send asynchronous commands to avoid occupying a single CPU core for a long time.
- PSP RING_BUFFER overcommitment allows batch command sending to the PSP using the RING_BUFFER data structure and overcommitment of empty commands in a specific format in the queue. When the PSP reads an empty command, it does not execute it until the C86

general-purpose processor writes a valid command. This optimization reduces the I/O overhead from C86 to PSP.

## Application Scenarios

The TKM can be used to manage keys in cryptographic servers, industrial control systems, key management systems, and other general systems. Based on TKM interfaces, interfaces complying with related standards can be encapsulated as required.

The TKM interfaces are SDF interfaces following GM/T 0018 specifications. The interfaces can be used in dedicated cryptographic devices, such as cryptographic servers, signature verification servers, and VPN servers. In addition, TKM-equipped Hygon servers can be deployed as cryptographic service nodes. This approach changes the cryptographic resource access mode from network access to local access and implements distributed cryptographic computing, delivering higher performance with lower costs and bandwidth consumption.

# Raspberry Pi

Raspberry Pi is a series of single-board computers developed by the Raspberry Pi Foundation and Broadcom. They are widely used in industrial automation, robotics, Internet of Things (IoT), education, and enthusiast projects due to their low price, small size, low power consumption, high programmability, and abundant ecosystem. Raspberry Pi 4B and Raspberry Pi 5 are classic products, both using Arm processors. Raspberry Pi 4B is a cost-effective entry-level computer, and Raspberry Pi 5 is an innovative product with significant performance breakthroughs and extended capabilities, making it competitive in high-performance edge computing.

## Feature Description

As typical open source hardware products, Raspberry Pi 4B and Raspberry Pi 5 support multiple Linux distributions such as Raspberry Pi OS, Ubuntu, and openEuler. They have extensive peripherals, powerful video encoding and decoding capabilities, LOM, and can be used as independent computer systems.

## Application Scenarios

Raspberry Pi 4B and Raspberry Pi 5 are widely used in many fields:

- **Education**: programming language learning such as Python, and electronic experiments using the peripheral interfaces
- **Multimedia and entertainment**: media center or game console
- **IoT and smart home**: sensor nodes or smart home hubs for environment monitoring, automation control, and edge computing
- **Server and network applications**: home servers, lightweight web services, and containerized applications
- **DIY projects**: robot control, 3D printing management, and drone flight control
- **Research and development**: AI experiments and prototype validation in embedded development
- **Industrial automation**: device monitoring, man-machine interface, and machine vision

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# 10 Appendixes

## Appendix 1: Setting Up the Development Environment

| Environment Setup | URL |
| --- | --- |
| Downloading and installing openEuler | https://openeuler.org/en/download/ |
| Preparing the development environment | https://gitee.com/openeuler/community/blob/master/en/contributors/prepare-environment.md |
| Building a software package | https://gitee.com/openeuler/community/blob/master/en/contributors/package-install.md |

## Appendix 2: Security Handling Process and Disclosure

| Security Issue Disclosure | URL |
| --- | --- |
| Security handling process | https://gitee.com/openeuler/security-committee/blob/master/docs/en/vulnerability-management-process/security-process-en.md |
| Security disclosure | https://gitee.com/openeuler/security-committee/blob/master/docs/en/vulnerability-management-process/security-disclosure-en.md |
| Security Strategy Overview | https://gitee.com/openeuler/security-committee/blob/master/docs/en/vulnerability-management-process/security-strategy-overview-en.md |