ICOS Key Exploitable Results

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Abstract

The unstoppable proliferation of novel computing and sensing device technologies, and the ever-growing demand for data-intensive applications in the edge and cloud, are driving the next wave of transformation in computing systems architecture. The resulting paradigm shift in computing is centered around dynamic, intelligent and yet seamless interconnection of IoT, edge and cloud resources in one computing system, to form a continuum.

ICOS aims at covering the set of challenges coming up when addressing this continuum paradigm, proposing an approach embedding a well-defined set of functionalities, ending up in the definition of an IoT2Cloud Operating System.

ICOS Full Stack

Cloud computing has evolved into a cornerstone of modern technology by enabling efficient sharing of centralized resources across applications and organisations, driving the adoption of integrated CEI ecosystems to transform processes, automate operations, and launch innovative services. Establishing a seamless CEI continuum – spanning data collection at the edge to cloud processing – is critical for Europe to build a globally competitive, secure, and data-agile economy, necessitating widespread adoption to maintain economic leadership, enhance societal resilience, and achieve sustainability goals.

Emerging paradigms like the Industrial Metaverse demand advanced Cognitive Cloud-Edge Continuum capabilities, requiring intelligent orchestration of physical-virtual integration through end-to-end AI, dynamic data management, adaptive cloud systems, decentralized optimization, and 5G/6G convergence – addressing challenges such as data inflation, heterogeneous data streams, and spatial-aware computing at the IoT-edge layer. Crucially, realizing this vision hinges on resolving cybersecurity, privacy, and interoperability gaps via secure SecDevOps practices, AI-integrated software lifecycles (SDLC/SOLC), cloud-edge data confidentiality frameworks, and open-source quantum-ready engineering models, underpinning Europe's transition toward a unified, trustworthy digital infrastructure.

Unique Value Proposition

ICOS offers a comprehensive solution for managing the CEI continuum with a complete set of features, including an AI repository. It effectively manages device diversity and network variability, optimizes performance, and reduces operational costs.

Key Benefits

- Streamlined Connectivity and Management: Tackles device volatility and network diversity with advanced virtualization, enhancing system adaptability and resilience.
- Optimized Performance and Security: Boosts service execution and performance and reduces power consumption while ensuring high security and privacy standards.
- Cost Efficiency and Flexibility: Lowers integration expenses and mitigates dependency on specific cloud providers, facilitating greater system flexibility.

An additional selling point is the modularity of ICOS offering, facilitating its integration with existing systems of adapting itself to specific customer requirements.

Offering

ICOS Full Stack is offered under an open-source business model, being the source code available while any additional service will be monetized.

There are two types of early adopters: i) XaaS providers with their own infrastructure that will incorporate ICOS as the master system to easiest the integration of their infra with the one owned by their customers, as well as facilitate apps deployment; and ii) organisations that develop apps and own their infrastructure, so they can use ICOS to manage the application lifecycle.

META-KERNEL Layer

Due to the increased adoption of IoT devices at different verticals, the need of processing data closer to the edge, mainly for legal restrictions on data management, has becoming even more important. At the same time, a fully integrated orchestration system is one of the most demanded tools by potential adopters. This is mainly because the existing systems must be integrated with new tools, thus, the learning curve is growing, while the orchestration systems must be able to manage the whole application lifecycle on highly heterogeneous and distributed environments making the process easier for users.

Unique Value Proposition

META-KERNEL Layer offers a fully integrated solution for monitoring, scheduling and orchestrating workloads across the continuum.

Key Benefits

- One single platform for orchestration management in distributed and heterogeneous environments.
- Modular and adaptable so it can be integrated with other existing solutions.
- It can be integrated with other layers to enhance its capabilities.

The META-KERNEL Layer is totally agnostic of the domain, so it can be adopted in different verticals.

Regarding competitors, there are several organisations providing orchestration tools to the market. However, there is a key factor of differentiation with them, and it is that ICOS META-KERNEL Layer is not only providing orchestration mechanisms, but also monitoring and adaptation, while it can be integrated with other layers according to specific user needs.

Offering

META-KERNEL Layer is composed of different open-source tools, and it is available in the project public repository for download. However, further monetization is done adapted to different stakeholders' needs, such as i) installation, adaptation and maintenance; ii) further developments including new features; and/or iii) integration with existing systems.

It can be also offered as a Service under a fee or sold as a bundle.

DATA Layer

The rapid growth of connected devices and real-time applications is driving a shift toward a decentralized edge-to-cloud continuum, where data is increasingly produced, processed, and acted upon at the network edge to meet demands for low latency, bandwidth efficiency, privacy, and resilience. Traditional cloud-centric models struggle with latency-sensitive and privacy-critical applications, and existing data management solutions often fail to unify communication, storage, and distributed processing, resulting in fragmented and inefficient systems.

Unique Value Proposition

The Data Layer offers a holistic and unified framework for managing data across the edge-to-cloud continuum by combining Zenoh for efficient, resilient data-in-motion and dataClay for distributed object storage and in-situ processing. Zenoh enables lightweight, low-latency, and fault-tolerant communication between heterogeneous devices, supporting peer-to-peer and publish/subscribe patterns ideal for constrained edge environments. DataClay complements this by providing seamless access to complex object graphs and collections, enabling in-situ computation, data locality, and transparent integration with third-party libraries. Together, these components create a vendor-neutral, cloud-native, and container-friendly platform that simplifies the deployment and management of distributed, real-time applications.

Key Benefits

This combination translates into concrete benefits for enterprises, governments, smart cities, energy operators, and system integrators. The framework reduces integration complexity, avoids vendor lock-in, and enhances operational efficiency, while enabling secure, real-time decision-making in latency-sensitive and bandwidth-constrained environments. By providing a unified, open-source solution that bridges communication, storage, and computation, the Data Layer empowers organizations to deploy scalable, resilient, and AI-ready infrastructures across heterogeneous environments. Unlike fragmented middleware stacks or centralized cloud solutions, it delivers a fully integrated, adaptable, and future-proof platform for the edge-to-cloud continuum.

Offering

The tool is offered under an open-source business model, allowing users to freely download and integrate it into their systems. There is no one single price as it depends on each specific customer needs, but there is some pricing schemes considered that must be further documented (and elaborated). Some estimations, based on use cases and open call winners' cases, will be also analysed. For enterprise customers, optional paid services are available, including professional deployment, maintenance, customization, and training. These services enable organizations to adapt the Data Layer to their specific data management requirements and ensure optimal performance and support across edge-to-cloud deployments.

SEC Layer

The Security Layer addresses the growing security complexity of the Computing Continuum (Cloud–Edge–IoT), aligning with Zero-Trust and DevSecOps adoption across hybrid, distributed environments, that require uniform security, trust and compliance controls.

Unique Value Proposition

Security Layer delivers a holistic, ready-to-use (or modular) solution for security, trust, and compliance across the cloud–edge–IoT continuum, closing the gap between fragmented point tools and organisations' need for unified protection and regulatory alignment.

Key Benefits

- Assessment of ICOS infrastructure and services security.
- Automated detection of compliance issues.
- Policy-driven triggers for infrastructure changes to restore compliance.
- Anomaly detection for emerging threats.
- Identity and access control.
- Secure, trusted communications within ICOS.

By design, the layer embeds DevSecOps and Zero-Trust practices across cloud and edge orchestrators (e.g., Kubernetes), closing the "last-mile" integration gap typical of point tools and reducing time-to-secure for adopters.

Offering

The Security layer business model combines an open-source baseline to lower adoption barriers with monetisation via paid support, training and feature customisation (and premium modules where justified). Pricing is tailored per costumer, with tiers and SLAs to be designed using benchmarks from use cases and Open Call winners.

Two early adopter profiles were validated: (i) XaaS providers operating their own infrastructure that will incorporate ICOS as the master system to ease the integration of their infra with the one owned by their costumers, as well as facilitate the deployment of applications; and (ii) organisations that both develop applications and own infrastructure, seeking secure, policy-driven lifecycle management. Priority verticals reflect common CEI use cases: agriculture (employee safety, asset monitoring), energy (employee safety, asset/fleet tracking, smart meters), healthcare (remote health monitoring, hospital asset tracking), manufacturing (asset monitoring, visual inspection), and transportation (driver and high-risk site safety).

INTEL Layer

The primary target market for the Intelligence Layer comprises small and medium-sized enterprises (SMEs) and mid-caps that possess their own infrastructure but lack the specialized in-house capabilities to leverage AI across their operational workflows effectively. While the solution is designed for broad applicability, early adopters are anticipated from sectors with immediate needs for edge intelligence and federated learning. These include smart homes, automotive (smart cars), critical infrastructure management, and smart agriculture, where use cases have already been identified within the ICOS project.

Unique Value Proposition

The Intelligence Layer's UVP is its delivery as an open-source, integrated AI-as-a-Service (AIaaS) platform that facilitates collaborative and federated learning across diverse devices and users within the edge-to-cloud continuum. This approach directly addresses the market's primary pain points: inefficient resource allocation, error-prone manual processes, unexpected system downtime, and a lack of actionable, real-time insights.

Key Benefits

- Forecasts and models to support smart workload orchestration: It provides forecasts used by the ICOS MetaOS to manage and optimize workloads across the continuum.
- AI performance monitoring: It provides robust AIOps capabilities, including experiment tracking and model management, allowing users to make informed decisions and ensure high levels of QoS/QoE.
- Trustworthy AI: Promotes trustworthy AI practices. Its federated intelligence support for the MetaOS keeps sensitive data localized on edge devices, enhancing privacy and security. It also integrates frameworks for explainable AI (XAI) in its experiment tracking feature to provide transparency and accountability.
- Model reusability and efficiency: Empowers users to reuse pre-trained models and supports model compression techniques for enhanced efficiency on resource-constrained edge devices.
- Edge-to-Cloud end-to-end solution: Unlike competitors who offer partial solutions, the Intelligence Layer provides a fully integrated suite of tools for data processing, model training, task offloading, and trustworthiness, specifically designed for the continuum.

Offering

The go-to-market strategy is built on a hybrid model that leverages the strengths of open-source distribution for widespread adoption while creating revenue through specialized enterprise offerings.

- First, the Intelligence Layer will be available as open-source software, free for download and modification. This fosters a community of users and contributors, accelerating innovation and adoption. Revenue will be generated through paid services, including professional installation, system customization, dedicated training, and ongoing maintenance contracts for enterprise customers.
- Second, a multi-channel approach will be employed to reach early adopters and the broader target market of SMEs and Mid-Caps. The strategy focuses on channels where developers, data scientists, and technical decision-makers are most active.

AI Models and Data Repository

The primary target market for the AI Marketplace encompasses a broad range of sectors that utilize machine learning, from resource-constrained embedded systems to large-scale cloud operations; as the prior KER, the focus is on small and medium-sized enterprises (SMEs) and mid-caps, which may leverage the repository to overcome the high barrier to entry in AI development. Early adopters are expected to be the active participants and leaders from the use cases developed within the ICOS project itself, specifically from sectors such as smart homes, automotive (smart cars), critical infrastructure management, and smart agriculture.

Unique Value Proposition

The Unique Value Proposition of this KER is its function as a specialized, centralized online catalogue for AI models and intelligent solutions specifically developed for and compatible with the ICOS ecosystem. It provides a portfolio of ideas and demonstrated use cases that significantly lower the barrier for users to adopt and benefit from ICOS services.

Key Benefits

- Reduced training time and cost: giving access to pre-trained models that can be fine-tuned, drastically reducing the time, computational resources, and costs of developing new models from scratch.
- Centralized and specialized repository: offering a single, curated location for a variety of AI models and solutions tailored for the edge-to-cloud continuum, improving model discovery and ensuring relevance.
- Simplified integration and deployment: providing tools, standardized formats, and docs to simplify the process of integrating and deploying models within existing systems.
- Fosters collaboration: Enabling knowledge sharing and collaboration among users, creating a supportive community dedicated to building intelligent applications for the ICOS context.

Offering

The go-to-market strategy is centred on an open-access model to encourage widespread adoption and community engagement, with a commercial layer built around value-added services.

The ICOS AI Model and Data Repository will be freely accessible to the open-source community. The codebase for the catalogue's integration with the Intelligence Layer will be published on platforms like GitHub, and the models and datasets themselves will be made available on platforms like Hugging Face: here, models will be open to everyone or private, depending on the contributor. This approach is designed to attract contributors and build a user base. Revenue generation will be driven by paid services offered by industrial partners, including specialized consulting, custom model adaptation, and formal training sessions for enterprise clients.