Innovation Potential of the ACCORDION Platform

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Abstract

The seamless utilization of resources in the cloud-edge spectrum is a key driver for innovation in the ICT sector, as it supports economic growth and strengthens the industry's competitiveness while making next-application services possible with minimal investments and disruption. In this context, the EU project ACCORDION provides an innovative three-layered architecture designed as a comprehensive solution dedicated to latency-aware applications. This paper summarizes the key technological innovations of ACCORDION, highlighting their alignment with the European agenda of the ICT sector.

CCS Concepts: • **Networks** → *Network resources allocation*; • **Human-centered computing** → **Ubiquitous and mobile computing design and evaluation methods**; • **Information systems** → *Computing platforms.*

Keywords: Edge Continuum, Resource Orchestration, Application Deployment, Edge Federation, Kubernetes

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1 Introduction

The vision of Edge computing is to abstract the heterogeneity of distributed computational resources to provide a more scalable and pervasive cloud-like experience to application developers, service providers, and end-users. The full realization of this vision is held back by several technological and conceptual challenges still under study by research organizations and industry stakeholders [3]. Such challenges must be tackled to ensure that solutions are valid despite a very dynamic market and technological landscape.

In this context, the ACCORDION[1] project designed and implemented an ambitious and comprehensive cloud-edge platform that targets QoE-aware applications. The platform proactively places application services to maximize QoE, and reactively changes the allocation plans in case of QoE degradations. ACCORDION was funded by the European Commission under the Horizon 2020 programme, started on January 1st, 2020, and finished on April 30th, 2023.

This paper briefly overviews the principal key innovations developed within the project, following the original project's vision [2]. In addition, we compare ACCORDION innovations against the EU agenda for next-generation ICT infrastructures, highlighting how ACCORDION covers many of its aspects.

2 ACCORDION Key Innovations

The ACCORDION Platform is composed of a collection of loosely coupled services organized in three main layers (see Figure 1). The Application Management Framework (AMF) layer offers an entry point for the application developers to deploy and prepare their applications for the ACCORDION system; The Continuum Management Framework (CMF) orchestrates the applications on top of the resources, which are represented in the third layer using the Minicloud abstraction developed in the project.

ACCORDION innovations span multiple areas and cut across all three platform layers. In the AMF layer, ACCORDION provides abstractions to the developers for hiding

[1] https://www.accordion-project.eu/

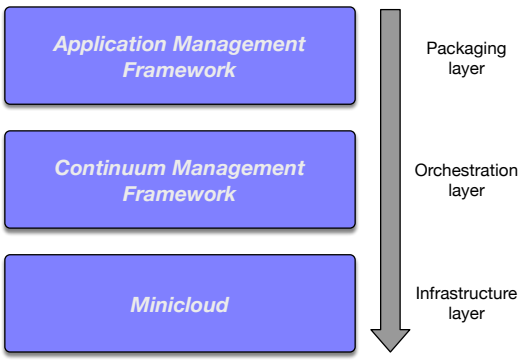

Figure 1. The 3-layered architecture of ACCORDION

infrastructure-level details for the application packaging and seamless integration with the ACCORDION system. It also offers an automated security auditing mechanism that checks the application as they are built and before deployments. At the CMF layer, the innovation resides with the event-driven orchestration of the application. The platform relies on high-level commands that gradually transform the application description into deployment files that meet appropriate high-level criteria. The CMF works reactively when the events come from the application and resource behavior analysis and can also work proactively by predicting a possible reduction of resource capacity and consequent degradation of the Quality of Experience (QoE) for the end users.

Finally, at the infrastructure level, the Minicloud abstraction [1] represents the computational and network resources of ACCORDION. The Minicloud has a strong geographical connotation due to the interactive requirements of the ACCORDION pilots. The Minicloud has been designed to support, within a uniform API, a range of heterogeneous architectures (such as x86 clusters, raspberry PIs, and Intel NUCs) and virtualization technologies (such as Docker containers, VMs, and Unikernels).

2.1 Application Management Framework

A core innovation of ACCORDION is to provide cutting-edge solutions to bridge proven and long-lived technologies with next-generation applications. To this end, the AMF integrates several open software tools in an automatic pipeline for compiling and packaging applications. In particular, the AMF uses Jenkins and Docker to pack the compiled code into the standardized images. During this phase, test results are analyzed with the Test Execution Analyzer (TEA), developed within the project, which evaluates the test log of applications built with the ACCORDION DevOps toolkit. TEA utilizes machine learning techniques to identify the test result's significance and if their content indicates that the application code is adequately tested. The TEA speeds up the application integration in ACCORDION, allowing developers to spot issues early on and correct them before the application is deployed. The images are then scanned by Trivy[2] for security purposes. The ready images are stored in a GitLab container registry ready for deployment at given resources.

2.2 Continuum Management Framework

The Continuum Management Framework (CMF) orchestrates application workflow deployment and runtime operations. Decisions on orchestration operations are based on application QoE optimization criteria. The CMF incorporates models that translate measurable parameters to application QoE metrics. This feature allows the CMF to take a more holistic approach to application management, considering not only technical parameters but also user experience. By incorporating QoE optimization criteria into orchestration decisions, the CMF ensures that applications are managed in a way that prioritizes user experience.

Furthermore, the CMF's focus on QoE optimization criteria indicates a forward-looking application management approach. As user expectations continue to evolve, the ability to manage applications based on QoE optimization criteria will become increasingly critical for organizations looking to provide a high-quality user experience. The CMF can be continually enhanced and optimized to improve its ability to monitor and manage the infrastructure supporting various applications. This can include the development of more sophisticated algorithms to detect and respond to changes in resource utilization and application QoE, as well as incorporating new technologies and architectures to improve scalability, reliability, and efficiency.

Furthermore, the CMF can be extended to support new types of applications and workloads, including emerging technologies such as AI, machine learning, and blockchain. This requires developing new tools and frameworks seamlessly integrated with the CMF to enable automated management and optimization of these applications.

2.3 Minicloud

The most important innovation offered by the Minicloud is its ability to pool heterogeneous edge resources geographically colocated under a single orchestration API. The minicloud sets up a set of services that manage the local orchestration operations and integrate with the ACCORDION's CMF. The Virtual Infrastructure Manager (VIM) offers an industry-standard API based on K3s, a lightweight Kubernetes distribution, to provision the deployment of containers and virtual machines. The deployment is made available through a single declarative YAML-based Kubernetes configuration instead of multiple low-level REST calls to the Kubernetes API. The storage management (ACES) provides access to local storage resources through both S3 and Posix interfaces and also implements a Registry component to cache both container and

[2]https://trivy.dev/

VM images, and a Syncer component to keep the registry up to date with its source. The Minicloud Monitoring configures Prometheus to collect both application (including VMs) and resource metrics. Data are made available both in the local Minicloud and in the CMF, via a distributed data structure implemented in the Resource Indexing and Discovery (RID) component. Finally, the Echoserver handles the registration of the Minicloud with the ACCORDION federation (i.e., the CMF) and provides functionalities for latency measurement of clients connected to the Minciloud.

2.4 Federation and Brokering Models

From a qualitative standpoint, ACCORDION follows a centralized brokered model. This implies that the central broker of ACCORDION recruits resource providers to become members of its managed federation. The recruitment subsumes the subscription of a business agreement, setting up the pricing of edge resources offered by the federation member, and the percentage of service revenue that the broker will keep once the resources are sold and allocated to a customer application. The resource metering necessary to enact the service agreements will be provided by the Monitoring component of the Minicloud, with a measurement of usage time for the involved resources.

ACCORDION centralizes the brokering of the federation in the CMF layer. Thus, all the events in the lifecycle of a deployed application impacting the federation business are handled by CMF, which acts as a broker. The broker will decide for instance to scale out (or in) the resources assigned to a given application, which will automatically turn into an update of given service revenues. There is no expectation of conflicts from the allocation of resources since this step is autonomously driven by each federation member, through the configuration of the RID component present in its own Minicloud. In other terms, the federation provider keeps regularly updated the profile of its own resources available for the federation; hence, there is no reason to foresee conflicts due to the provider's rejection to let its resources be allocated. When a federation member wants to remove resources from the federation, it only must remove them from available Kubernetes nodes.

Another relevant event in the ACCORDION application lifecycle is the migration of an application to a different Minicloud. Even in this case, there are no expected conflicts: the source Minicloud cannot oppose the migration, and the target Minicloud has to accept to host the resources for the application.

3 Alignment with the EU Agenda

The ACCORDION innovations align with the EU agenda for next-generation ICT infrastructures[3], which seeks to achieve a twin green and digital transition by 2050, with a vision for a carbon-neutral, open, and distributed digital future that leverages sustainable technologies and fosters innovation and competitiveness.

One of the critical aspects of the EU agenda is to promote green clouds and green data centres, which can reduce energy consumption and greenhouse gas emissions from ICT infrastructures. The ACCORDION platform contributes to the green transition in several capacities. ACCORDION optimizes resource allocation and orchestration across edge, and cloud layers with an efficient placement of application on edge resources closer to end users and their devices. This helps reduce long-range communication and data transmissions, with a consequent reduction of energy waste. Furthermore, ACCORDION exploits lightweight virtualisation technologies (such as Unikernels) that naturally reduces application footprint and data transfers.

Another aspect of the EU agenda is fostering open standards and interoperability among ICT infrastructures. The ACCORDION platform supports the digital transition by adopting open standards and interoperability among different ICT infrastructures. ACCORDION based part of its design on the MEC (Multi-access Edge Computing) paradigm, which provides standard interfaces for deploying applications at the edge. ACCORDION also leverages open-source software components such as Kubernetes, TOSCA, and Docker, enabling applications' portability and scalability across heterogeneous environments.

A third aspect of the EU agenda is stimulating distributed innovation ecosystems involving multiple stakeholders across different sectors and regions. The ACCORDION platform stimulates distributed innovation ecosystems that involve multiple stakeholders across different sectors and regions. The project involves a diverse consortium of partners from academia, industry, and end users who collaborate on developing cutting-edge solutions for next-generation applications. Finally, ACCORDION enables SMEs to enhance their competitiveness and growth potential by accessing advanced ICT infrastructures that meet their specific needs.

[3]https://www.europarl.europa.eu/factsheets/en/sheet/64/digital-agenda-for-europe

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