Cloud Computing for Enhanced Living Environments

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Enhanced living environments, supported by optimized algorithms, architectures, and platforms, can help individuals needing assistance maintain autonomy and improve quality of life.

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Enhanced living environments (ELEs) support the seamless integration of information and communication technologies (ICT) within context-aware homes and residences. ELE research aims to create smart and safe environments around people needing assistance, such as the elderly and people with disabilities, to help them maintain an independent lifestyle, reduce health and social care costs, and achieve improved quality of life and advanced autonomy, mobility, social interaction, self-confidence, independence, and social inclusion.

Efforts in this area are supported by optimized algorithms, dependable architectures, and efficient platforms, converging to the realization of ambient assisted living (AAL) systems. AAL systems utilize pervasive devices and ambient intelligence to construct smart and safe ELEs.[1] Important issues relate to the missing interaction of multiple stakeholders needing to collaborate for ELEs, supporting a multitude of AAL services.

Many fundamental technical issues in the ELE area remain open. Starting with the infrastructure used for data harvesting, a major concern for ELEs is the efficient use of sensors for daily data collection, storage, and mining. Adding human society as another dimension lets us define a new type of system, *cyber-physical-social systems*, where ICT (cyber), intelligent devices (physical), and human society (social) come together to provide high-quality AAL services to improve users' quality of life. Even if this approach is successfully applied at large scale in smart cities,[2] most current efforts still don't fully take into account the power of human beings and the importance of social connections and societal activities.

A strong approach in building ELEs utilizes implantable and wearable sensors, and wireless sensor networks (WSNs) that are supported by cloud computing.[3] For people with disabilities or for elderly people requiring constant care, the emergence of ubiquitous computing paradigms, empowered by 5G wireless communications, plays an essential role in providing better living environments. Cloud computing has been an empowering force for this endeavor, albeit raising several ethical, security, and user experience issues. However, the ELE technology and data could be vulnerable to cyberattacks and exploitations, which can lead to life-threatening scenarios such as incorrect medical diagnoses.[4]

Effective ELE solutions require appropriate ICT algorithms, architectures, and platforms, with a view toward the advancement of science in this area and the development of new and innovative connected solutions (particularly in pervasive and mobile systems). Mobile platforms can now bring the computation power made available by highly advanced datacenters closer to the user. In addition, the actual interconnection between mobile and cloud systems is possible by combining the capabilities of individuals, as they interact with each other, through a well-designed ubiquitous technology. Platforms of tomorrow will benefit from this combination through the help of new models for understanding the environment (such as participatory and opportunistic mobile sensing), performing computation (for example, mobile cloud computing), or even exchanging data via mobile ad hoc networks. These issues are supported by intercloud architectures and progressive integration of sparse, geodistributed resources into big datacenters, where energy-efficient message-exchanging models are already developed.[5]

Many ELE applications are used by people with special needs (such as the elderly and people with disabilities), with 24/7 continuous monitoring and control of the environment, and access to care services when needed. One important problem is the expectation and acceptance of new technologies by these populations. The solution is to provide transparent and noninvasive platforms with minimal interaction between the ICT platform and the user. Moreover, ELE applications should be strongly user-oriented, involve users at all stages, collect the necessary information anytime, anywhere, and provide feedback to improve quality of service (QoS).

Overview of the Special Issue

We organized this special issue in the context of the Architectures, Algorithms, and Platforms for Enhanced Living Environments (AAPELE) European cooperation in the field of scientific and technical research (COST) Action, a wide and powerful research network oriented on ELE (www.cost.eu/COST_Actions/ict/Actions/IC1303). The goal was to bring together state-of-the-art research efforts addressing

advanced cloud computing challenges and solutions for realizing ELEs. Topics of interest included:

- Computational intelligence for smart ELE
- Cloud-based architectures and platforms for ELE
- Cloud-based testbeds, prototypes, and practical systems for ELE
- Smart sensing and monitoring within ELE
- Adaptive mobile cloud computing
- ICT instrumentation and middleware support for smart ELE
- Mobile applications, networks, and systems
- Applications for ambient assisted living environments
- Human-computer interaction within ELE
- Multimodal user interfaces for ELE
- Efficient algorithms for ELE data collection, fusion, and mining
- Innovative cloud services and applications for ELE
- Multimedia content delivery
- Services for location and context sensing and awareness
- Security and communication aspects related to ELE
- Performance evaluation of existing cloud computing technologies for ELE

All submissions underwent rigorous review, at the end of which we accepted five papers for publication in the special issue.

In "Internet of Things Architecture for Enhanced Living Environments," Stylianos Balampanis, Stelios Sotiriadis, and Euripides G.M. Petrakis present an Internet of Things (IoT) platform that connects users, their devices, and a cloud-based system in a modular way, by separating modalities into independently deployed cloud services. Their use case focuses on patient monitoring for enhanced living using motion-sensing devices. The proposed platform aims to reduce costs and support real-time data collection. By offering real-time prevention with continuous monitoring, the authors show that they can establish a rehabilitation environment with an improvement treatment process by allowing caregivers access to real-time information such as patients' temporal health status and their reaction to a given therapy.

In "A Tensor-Based Big Service Framework for Enhanced Living Environments," Xiaokang Wang, Laurence T. Yang, Jun Feng, Xingyu Chen, and M. Jamal Deen present a three-plane framework for building cyber-physical-social systems to provide high-quality services in ELEs. In the sensing plane, a local tensor represents the relationship of objects in every local system. The tensor is then cleaned and uploaded to the cloud plane, where a global tensor is constructed for subsequent use in the application plane for various applications, per the case and scenario requirements. The authors present a smart home case study as an application of the proposed service framework.

In "Secure and Resilient Cloud Services for Enhanced Living Environments," Jesus Pacheco, Cihan Tunc, Pratik Satam, and Salim Hariri present a platform that offers secure and resilient services for ELEs. The end nodes in this platform oversee the collection of ELE variables that are stored in the cloud using a secure gateway, which manages communication between the end nodes and the cloud using biocyber metrics for authentication. The cloud-based platform provides the required ELE services in an anytime, anywhere manner, resilient to main security attacks.

In "A Fog-Based Emergency System for Smart Enhanced Living Environments," Yannis Nikoloudakis, Spyridon Panagiotakis, Evangelos Markakis, Evangelos Pallis, George Mastorakis, Constantinos X. Mavromoustakis, and Ciprian Dobre present a virtualized fog-based infrastructure for harvesting and managing distributed heterogeneous resources, shifting the entire cloud functionality to the network edge. Their system uses the cloud in an assistive manner to ensure resource-wise robustness of the system. The authors use the proposed infrastructure to support an AAL emergency system that alerts the nearest responding authority in case of an emergency involving the target user. The system utilizes an outdoor positioning mechanism, emergency protocols, and IoT communication protocols.

Finally, in "Overcoming Barriers for Ubiquitous User-Centric Healthcare Services," Alex Palesandro, Chirine Ghedira Guegan, Marc Lacoste, and Nadia Bennani introduce Orbits, an infrastructure-as-a-service-level architecture enabling flexible and legacy intercloud application deployment for mobile remote healing, while providing a homogeneous service abstraction across multiple clouds. The authors propose Orbits for home healthcare systems to ensure transparent usage of resources from multiple providers enabling "follow me" scenarios, where healthcare services are accessible anytime, anywhere with QoS guarantees. The authors present a work-in-progress prototype with several benchmarks to demonstrate the approach's viability and highlight the key implementation choices.

We hope that in this special issue readers will find interesting solutions and ideas for research in the ELE/AAL field. We are grateful to all the reviewers for their excellent and rigorous work in finalizing the reviews on time, as well as the authors for submitting their papers to this special issue. We would like also to thank Editor-in-Chief Mazin Yousif and the *IEEE Cloud Computing* team for the editorial assistance and excellent cooperative collaboration.

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