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Special issue on Edge Computing in Pervasive Systems

Claudio Cicconetti (IIT-CRN, Italy), Antonio de la Oliva (Universidad Carlos III de Madrid, Spain), Dario Pompili (Rutgers University, USA)

Editorial

Edge computing was born as a complement of cloud computing to enable niche applications with low delay requirements, which thus had to be close to the end users. However, it has recently become pivotal to the deployment of new communication and computation infrastructures, with a portfolio of applications that can benefit from the advantages of pervasive compute power, which is growing every day thanks to further advantages of edge computing in terms of reduced Internet traffic and increased privacy of data. As a matter of fact, edge computing is crucial for many of the new 5G business vertical use-cases, such as Industry 4.0 robots, safety-critical communications, and highly-efficient smart grids. However, the tighter integration of such impactful businesses into previously core network operations raises significant security, trustworthiness, and reliability issues. A business vertical must not compromise the edge platform to other business verticals. Likewise, the vertical network services entrusted to the edge should not be compromisable by adversary action.

We envision that pervasive edge computing will unlock the full potential of several high-impact applications, like autonomous driving, real-time data analytics and automated decision making, Industry Internet of Things (IIoT), Internet of drones, mobile online gaming, and Augmented/Virtual Reality (AR/VR). The current market of edge computing, which is already estimated at 3.6 billion USD, is projected to reach 15.7 billion USD in 2025.

However, as the edge computing ecosystem has been growing and becoming more mature, novel research challenges have emerged to improve performance evaluation models and tools, to seek further optimization opportunities, and to target radically new scenarios. The call to action has been answered by the research community, which is currently devoting significant efforts to various aspects of edge computing. Therefore, we have decided to edit a special issue on Edge Computing in Pervasive Systems, which collects 12 high-quality contributions on relevant topics at the forefront of research, out of 35 manuscripts received.

The paper “Assessing the Impact of Unbalanced Resources and Communications in Edge Computing”, by Luiz Angelo Steffenel, Manuele Kirsch Pinheiro, and Carine Souveyet, explores the concerns on unbalanced and heterogeneous resources at the edge with a dataset-driven approach that seeks to understand better data locality and context awareness. Thanks to the results obtained, they have identified several performance bottlenecks that may hinder an edge application, including the difficulty to place the data where it needs to be, the need for awareness about data locality, and the node runtime context during the application deployment.

The paper “Distributed Algorithms Based on Proximity for Self-Organizing Fog Computing Systems”, by Vasileios Karagiannis and Stefan Schulte, addresses the issue of pervasive edge systems being dispersed over a large geographical areas, often with an irregular topology, by proposing a solution to let the nodes self-organize into a hierarchical structure based on distributed network proximity measurements. They have shown that the proposed algorithms can decrease the communication latency of latency-sensitive processes by 27%–43%, and increase the available network bandwidth by 36%–86%, in the scenarios considered.

The paper “Modeling Intelligent Controller for Predictive Caching in AR/VR-enabled Home Scenario”, by Sharare Zehtabian, Siavash Khodadadeh, Ladislau Bölöni, and Damla Turgut, aims at delivering information at the maximum quality for AR/VR applications, and at optimizing the delivery cost accordingly by predicting the user’s requests. They have used two real-world and two simulated datasets and proposed long short term memory (LSTM) networks and probabilistic local caching strategies. The results have shown that the prediction accuracy depends significantly on the size and density of the dataset.

The paper “EdgeDoc: An Edge-based Distributed Collaborative Editing System”, by Mona Mohammed Alghamdi, Asma Cherif, and Abdessamad Imine, provides an innovative take to real-time collaborative editors by using a Mobile Edge Computing (MEC) deployment to clone mobiles and offload resource-intensive tasks whereas lightweight edition components are handled locally. Results show a significant improvement of the responsiveness of such collaborative systems.

The paper ”Modeling and Performance Analysis of Smart Map Application in the Multi-access Edge Computing Paradigm”, by Reza Shojaee and Nasser Yazdani, presents a detailed analysis of the possible performance bottlenecks and key parameters to consider when using MEC technology in the Smart Maps application. The paper focuses on performance modeling and analysis of direction-finding in a map application. The authors study the impact of variation of workload, number of servers, queue length, and connection failure in terms of task rejection probability as well as mean sojourn time. The analysis can serve to assess the MEC platform performance under similar applications.

The paper “MyDigitalFootprint: An Extensive Context Dataset for Pervasive Computing Applications at the Edge”, by Mattia Giovanni Campana and Franca Delmastro, presents a novel large-scale dataset composed of smartphone embedded sensors data, physical proximity information, and online social networks interactions aimed at supporting multimodal context-recognition and social relationships modeling. The value of this dataset is evaluated on three types of Machine Learning (ML)-based applications, i.e.: (i) social link prediction based on physical proximity data, (ii) recognition of daily-life activities based on smartphone-embedded sensors data, and (iii) pervasive context-aware recommendation.

The paper “Relevant Node Discovery and Selection Approach for the Internet of Things Based on Neural Networks and Ant Colony Optimization”, by Abderrahim Zannou, Abdelhak Boulaalam, and El Habib Nfaoui, provides a novel edge-driven approach to the service discovery and selection in IoT networks. The discovery phase is performed by an edge server using a neural network; the selection phase is performed to select the most adequate node from the set of relevant nodes using Ant Colony Optimization (ACO). Experimental results show high performance in terms of accuracy and a longer network lifetime for both the discovery and selection phases as well as a short period of time for both phases.

The paper “Energy and Task Completion Time Trade-off for Task Offloading in Fog-enabled IoT Networks”, by Om-Kolsoom Shahryari, Hossein Pedram, Vahid Khajehvand, and Mehdi Dehghan TakhtFooladi, focuses on improving the quality of experience in executing computation-intensive tasks of real-time IoT applications in a fog-enabled IoT network, where resource-constrained IoT devices can offload tasks to resource-rich nearby nodes. Such approach generates a reduction in energy consumption compared with local processing, although it extends task completion time due to communication latency. Specifically, the authors propose a task-offloading scheme that optimizes offloading decision, fog-node selection and computation-resource allocation, and investigate the trade-off between task completion time and energy consumption. The authors formulate the task-offloading problem as a Mixed-Integer Non Linear Program (MINLP), which is NP-hard, and solve it via a novel sub-optimal algorithm based on the hybrid of genetic algorithm and particle swarm optimization.

The paper “GEESE: Edge Computing Enabled by UAVs”, by Mohan Liyanage, Farooq Dar, Rajesh Sharma, and Huber Flores, investigates how cloudlets can be transported by Unmanned Autonomous Vehicles (UAVs) to provide computation support on the edge. Fortunately, cloudlets are becoming portable enough such that they can be transported and integrated into any environment easily and dynamically. Based on this study, the authors develop GEESE, a novel UAV-based system that enables the dynamic deployment of an edge computing infrastructure through the cooperation of multiple UAVs carrying cloudlets. By using GEESE, they conducted rigorous experiments to analyze the effort to deliver cloudlets using aerial, ground, and underwater UAVs. The results indicate that UAVs can work in a cooperative manner to enable edge computing in the wild.

The paper “Joint Radio and Local Resources Optimization for Tasks Offloading with Priority in a Mobile Edge Computing Network”, by Youssef Hmimz, Tarik Chanyour, Mohamed El Ghmary, and Mohammed Ouçamah Cherkaoui Malki, considers subscribers with a priority property fixed by their contracts with the service provider and studies a multi-server MEC network with multiple base stations where each one is equipped with a MEC server and provides offloading services to nearby users. The authors consider the energy consumption, the critical situations of radio resources’ insufficiency as well as a penalty function based on priority, and formulate a bi-objective optimization problem that jointly minimizes the overall energy consumption and the penalty function while allocating the local processing frequencies, the transmit powers, and the radio resources allocated by the base station. Then, based on the weighted aggregation approach, the authors propose and study the performance of a novel heuristic solution called Resources Allocation with Priority Devices (RAPD).

The paper “Optimal Edge Server Deployment and Allocation Strategy in 5G Ultra-dense Networking Environments’, by Bo Li, Peng Hou, Hao Wu, and Fen Hou, exploits the new paradigm of Ultra Dense Networks (UDN) to meet the requirements of explosive data traffic in 5G mobile communications so as to improve regional spectrum efficiency and network coverage. Specifically, the authors proposed an optimal deployment and allocation strategy for deploying Edge Servers (ESs) in a UDN to minimize the cost of service providers and to guarantee the completion time of services. Based on queuing theory and vector quantization technique, the proposed strategy is shown to be able to determine the optimal number of ESs, their locations, and mobile users allocation for a given UDN. Experimental results show that such strategy is superior to existing algorithms in both qualitative and quantitative aspects, and can minimize the cost of deployment while guaranteeing mobile users’ requirements on offloaded tasks’ completion time.

The paper “TOTP Moving Target Defense for Sensitive Network Services”, by Vitor A. Cunha, Daniel Corujo, Joao P. Barraca, and Rui L. Aguiar, proposes a Moving Target Defense (MTD) mechanism that protects sensitive Network Services (NSs) using a port mutation akin to a seamless Time-based One-Time Password (TOTP) authentication. Inspired by the existing Internet Services Two-Factor Authentication (2FA) systems, the proposed architecture leverages Software Defined Networking (SDN) to perform the mutations, having the option of working exclusively as a Virtual Network Function (VNF) that can be instantiated on-demand, or in conjunction with OpenFlow hardware-accelerated switches for smarter resource usage. A proof-of-concept implementation showed that the approach is viable, with good forwarding plane performance (exceeding the current Network Interface Controllers capabilities), and effective at stopping the unauthorized interactions with the network services to be protected.

We believe that these 12 accepted papers will raise awareness on many novel topics of growing interest, and will advance knowledge on more stable research areas, in both cases resulting in high interest to the readers of the Elsevier’s Pervasive and Mobile Computing Journal.

We wish to thank all the authors of the submitted papers for their high-quality contributions, including those who could not be accepted for publication in the special issue, as well as the many anonymous reviewers for their dedication in providing timely and thorough reviews of the papers assigned to them. Their informative comments and insightful suggestions have been fundamental to not only evaluate the submissions but also improve the quality of the accepted papers. Last but not least, we wish to thank the EiC Prof. Sajal K. Das and the EiC for special contents Prof. Marco Conti for their continuing support throughout the process while hosting and organizing this special issue.