Guest Editor's Introduction

Living on the Edge

Charalampos Z. Patrikakis
University of West Attica

Maria R. Lee
Shih Chien University

Phillip A. Laplante
Pennsylvania State University

***Abstract*—"Such gliding wonders! such sights and sounds! Such join'd unended links, each hook'd to the next! Each answering all—each sharing the earth with all." (Walt Whitman, "Salut au Monde" [Greeting to the World: from Leaves of Grass], 1856)**

While trying to think of an appropriate introduction to this special issue of IT Pro, the above verse from Walt Whitman's "*Salut au Monde*" came to mind. Though it does not refer to modern networks and our internet world (after all it was written more than 150 years ago), it describes in the most characteristic way an ecosystem where humans, animals, devices, and even software do not simply connect, but participate, share, and contribute: the Internet of Things. Here, as it has happened in the past with the substitution of mainframe computers by personal computers, and the adoption of the concept of simple networks/smart terminals (over which the whole idea of Internet protocols has been based), it is the increased computational capabilities of terminal devices that drives the evolution. This continuously increases the power of edge devices to store and process data, which can be described through one term: Edge Computing.

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BEYOND THE CLOUD

Stepping on the foundations of Cloud Computing, Edge Computing comes as an evolution toward a reducing latency and minimizing computational load and storage requirements over the cloud. The ability to move the computational functionality at the edge, apart from the potential for scalability it introduces, comes with several benefits over the traditional cloud computing model: low jitter, location awareness, high mobility support, and privacy protection. On the other hand, the enormous needs for processing and storage in the era of big data require the introduction of hybrid models, enabling the combined use of (core) cloud and the edge computing in serving the needs of next generation internet services.

PROMISES OF EDGE COMPUTING

Edge Computing comes with a promising proposal: Having data produced by IoT devices stored and processed close to where it is created instead of transmitting it to data centers or the clouds. The pros of this proposal are many, providing ground for solutions to many issues raised in out always connected universe.

First of all, there is the issue of minimizing traffic, and latency, in which Edge Computing comes to offer the potential to dramatically decrease the time it takes from the capturing of data, to the production of meaningful information, and decisions. The ability to execute complex calculations and apply computational logic at the edge eliminates the need for high speed, low latency connections to data centers and minimizes the response times.

Second is the issue of energy consumption, where the ability to locally process data, apart from eliminating the need for temporal remote transmission and storage, allows for distributed/edge processing, which significantly reduces energy consumption. Last, but not least, there is the issue of privacy and data protection. The ability to locally process data at the point where they were collected or created can ensure that personal or sensitive data are not sent to any third party. This is quite important in cases of personal devices such as mobile phones, smartwatches, and health related devices.

EXPLOSIVE GROWTH FOR THE EDGE COMPUTING MARKET

According to Forrester's Global Business Technographics Mobility Survey for 2018,[1] major cloud vendors are already offering edge computing services, while in the same survey, 27% of global telecom decision-makers said their firms are either implementing or expanding edge computing. The global edge computing market is expected to have an explosive growth, reaching a value of USD 3.24 billion by 2025, according to the Edge Computing Market Size & Forecast Report, 2016–2025.[2] The advent of wearable smart devices such as smartwatches and smart glasses is expected to fuel this growth, allowing users to process data generated by IoT devices locally rather than transmitting them to remote data centers, saving on time and bandwidth, while preserving in parallel privacy over personal information.

Since device intelligence is increasingly becoming a synonym of artificial intelligence, it is AI at the edge which is also supporting this growth. In Tractica's report "Artificial Intelligence Edge Device Shipments to Reach 2.6 Billion Units Annually by 2025,"[3] it is estimated that AI edge device shipments will increase from 161.4 million units in 2018 to 2.6 billion units worldwide annually by 2025, with AI incorporated in consumer devices such as drones, security cameras, smart speakers, automobiles, and consumer robots.

ROLE OF ARTIFICIAL INTELLIGENCE

Currently, AI processing is mostly done using a centralized approach, where the edge devices are used to either collect (through their sensors) and transmit data to a remote data center for processing and/or receive the inference part of the AI workflow. The main reason for this is the lack of the necessary processing power for completing the processing part of the AI workflow. However, this is changing: The enormous growth in computational capability of consumer devices over the last years, with the GPUs providing the horsepower, together with the needs for privacy, security, and cost minimization, are paving the path for AI for edge devices.

Applications featuring the use of Deep Learning at the edge have started to appear, like the recently presented work in PERCOM 2019: "Gesture-based incident reporting through smart watches"[4] in which smartwatches, through the use of Deep Learning, are able to locally process sensor data and understand user-defined gestures in order to generate incident reports, but it is not only research efforts that focus on the use of AI at the edge. According to Forbes, there are a huge number of startups focused on creating infrastructure for a smarter edge, like SWIM.AI, aiming at bringing self-learning AI to the edge.[5]

DRIVING FORCE BEHIND NETWORK EVOLUTION

Another domain in which the contribution and potential benefits from the adoption of edge computing has been acknowledged is that of next generation networks. The European Telecommunications Standards Institute (ETS) has established the Mobile Edge Computing (MEC) Industry Specification Group, working toward the standardization of mobile edge computing.[6]

MEC provides an IT service environment at the edge of the mobile network, in close proximity to mobile subscribers, which is considered to be the natural development in the evolution of mobile base stations, recognized by the European 5G Infrastructure Public Private Partnership research body as one of the key emerging technologies for 5G networks.[7] The potential of MEC in supporting a low latency, high bandwidth, location awareness over radio networks creates added value and a framework for improvement and monetization of a rich media, mobile broadband experience.

IN THIS ISSUE

All the above reveal the benefits that edge computing has to offer to next generation computing and communications. For this, we have dedicated this special issue to the trends, challenges, and applications related to the engineering and operational aspects of edge computing. The articles include research and development focusing on mobile edge servers and privacy awareness forecasting.

In the first article, "The Rise of Proximal Mobile Edge Servers," Muhammad Habib ur Rehman, Aisha Batool, and Khaled Salah aim to address the challenge of applying proximal mobile edge servers for data analytics applications to minimize network latency, lower dependencies on Internet connectivity, and reduce the cost of cloud services. They present three different types of mobile applications experimental evaluations, whereby App1, App2, and App3 use J48, naive Bayes, and random forest on the feasibility of opportunistic usage of mobile edge servers. The results demonstrate that mobile edge servers may be a viable choice when compared to fixed edge servers in mobile environments. The authors also summarize future challenges and research directions for mobile edge computing. They suggest to improve better data and computation offloading strategies in M2M communication models, different mobility models, comovement patterns, device usage statistics, and application execution histories should be considered.

The second article presents a privacy aware approach by applying edge computing technology to predict travelers' places of interest. In "Exploiting Edge Computing for Privacy Aware Tourism Demand Forecasting," Christos Chatzigeorgiou, Panagiotis Kasnesis, and Lazaros Toumanidis demonstrate the use of edge computing to reduce the amount of sensitive data that have to be transferred over the internet. They authors propose a Federated Collaborative Filtering-based solution to recommend places to its users without exposing their private data in the risks of the internet and minimizing the need for constant network access. Federated learning pairs excellent with edge computing as it allows training of machine learning (ML) algorithms on remote devices. Personalized recommendations are possible because the training of the algorithm makes use of users' data and solves the "cold-start" problem of recommendation systems. The results indicate exploiting edge computing leads to less bandwidth, saving energy, and transmission costs and improves computational time and user experience.

REFERENCES

1. Forrester, "Global business technographics® mobility survey," 2018.
2. Million In$ights, "Edge computing market size & forecast report, 2016–2025."
3. Tractica, "Artificial intelligence edge device shipments to reach 2.6 billion units annually by 2025," 2018.
4. P. Kasnesis, C. Chatzigeorgiou, L. Toumanidis, and C. Patrikakis, "Gesture-based incident reporting through smart watches," in *Proc. IEEE PERCOM Wristsense Workshop*, Kyoto, Japan, 2018.
5. D. Woods, "Why AI at the edge is the next goldmine," *Forbes*, 2018. [Online]. Available: https://www.forbes.com/sites/danwoods/2018/04/04/why-ai-at-the-edge-is-the-next-goldmine/#65da71eeecfe
6. Y. C. Hu, M. Patel, D. Sabella, N. Sprecher, and V. Young, "ETSI white paper no. 11: Mobile edge computing, a key technology towards 5G," First ed., Eur. Telecommun. Stand., Inst., Sep. 2015.
7. 5G Vision: The 5G Infrastructure Public Private Partnership: The next generation of communication networks and services. From The 5G Infrastructure Public Private Partnership. [Online]. Available: https://5g-ppp.eu/wp-content/uploads/2015/02/5G-Vision-Brochure-v1.pdf