Workshop: Converge of Edge Intelligence in IoT (EdgeA-IoT 2022)

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***Abstract* — Edge Intelligence is a synergy that seems to be imperative to conclude the convergence of the Edge Computing and Internet of Things to support intelligent application very close to end users. IoT has pervaded our daily life by making things, interconnected through the Internet, smarter, distributed and more autonomous. The emerging development of intelligent applications in IoT has now started to gain significant attention. Cloud provides many benefits to IoT devices, including high-performance computing, a storage infrastructure, processing and analysis of large-scale data giving to IoT the opportunity to be robust, smart and self-configuring. The forthcoming emergence of Edge AI will extend the capabilities of the 'legacy' IoT, its potentials, the number of devices and the volumes of data. However, Cloud technologies face some accessibility challenges when providing services to end-users. For instance, mobile clients can move among different places, yet require Cloud services with minimum cost and short response time. The unstable connection between Cloud and mobile devices is expected to prevent providers from achieving the optimal performance. To cope with these limitations, we aspire that Edge AI converged with IoT environments materializes the desired AI-led distributed and ubiquitous intelligence in real computing systems. We then need additional effort to establish and deliver the convergence of Edge AI and IoT in formatting the future Intelligent IoT. The Intelligent IoT is envisioned to involve numerous autonomous & distributed computing and AI-driven entities capable of understanding their internal status (context), the status of their environment and peers (collaborative context) and take timely optimized actions to efficiently serve modern applications, like tactile internet and augmented AI-led gaming.**

Index Terms* — *Edge AI; Intelligent Edge; Collaborative Context Aware Applications; Distributed AI; Edge AI Infrastructure Modelling; Computational Intelligence

PAPERS PRESENTERS & SPEAKERS

Workshop Link: https://wfiot2022.iot.ieee.org/track-1/

- Invited Talk: *Human-Centred Machine Learning in Healthcare Applications beyond Clinic*, presented by F Deligianni.
- *Predictive Model Resilience in Edge Computing*, presented by Qiyuan Wang, University of Glasgow
- *Computation Offloading with Reinforcement Learning for Improving QoS in Edge Computing Environments*, presented by Jinho Park, Kwangwoon University.
- *Artificial Intelligence for Cybersecurity in IoT-enabled Avionics: Challenges and Solutions*, presented by Ranwa Al Mallah and Mohammad Alja'afreh Royal Military College of Canada.
- *Benchmarking of Emulated Wireless Edge Cloud Connectivity for Maritime Environments*, presented by Antti Kolehmainen, Tampere University

CHALLENGES, QUESTIONS & DISCUSSION OUTCOME

Question I: *Big challenge is the management of highly distributed environments over IoT data*.
The participants agreed on that the main challenges in Internet of Things (IoT) systems remain: (i) the efficient contextual data collection, (ii) routing and management of data streams from heterogeneous sources, including sources with high ingestion rates. Despite the existence of various IoT data streaming frameworks, there is *still no* efficient way for collecting and routing IoT streams in configurable ways that are easy to be implemented and deployed in realistic environments. Research topics that are active in this challenge include programmable engines for distributed data analytics, which are expected to support the tasks of collecting IoT streams from different heterogeneous sources. Moreover, part of this challenge includes the management of smart IoT devices. IoT-enable Edge Computing environments enable acceleration of this research topic by introducing new intelligent techniques and paradigms in light of making IoT applications secure, scalable, energy-efficient, and capable of working in mission-critical use cases. Such applications due to data privacy issues and/or constraints in data transfer should be able to function offline in an autonomous manner. In this context, novel combination of e.g., distributed ledger technology and distributed intelligence can be envisaged as a practical decision towards decentralizing IoT architectures in light of efficient management.

Question II: *How do you foresee the future of Edge Computing?*

There were multiple perspectives of the future of Edge Computing given the highly applicable capacity in distributed data-driven environments. The summary on this aspect boils down to the fact that the edge computing looks strong, primarily because of the technological innovations it will allow in different domains of data management and control of distributed devices. Specifically, edge computing will be applied to all the cases when data and information are moved closer to the applications/end-users tasks. History has shown that most data stored in the Cloud does not scale with the number of devices generating new and complex data. The challenge with this paradigm is that when the applications require access the data, the process can be slow because the data are not accessible or sometimes not even availably close to where the users tasks is located. It is therefore reality, which will continue in the near future that with edge computing, data re processed close to the original source and can speed up the process significantly. Another aspect is the rise of IoT devices. It was mentioned that in the future, we'll see an increased push and adoption of IoT systems, especially as 5/6G becomes widely available. Futuristic smart homes and self-driving cars will be made possible with edge computing. Self-driving vehicles along with platoon vehicles will need quick data processing and inference that comes with pushing intelligence at the network edge. Moreover, in healthcare and manufacturing, remote monitoring using IoT devices will be anticipated for ongoing visibility into patients' healthcare records (including applications like alerts to patients and doctors when vitals are out of range). Unanimously, options are endless when IoT pairs with edge computing.

Question III: *Is it possible to use Edge Computing without using Cloud services?*

Nowadays, edge computing certainly has the edge over Cloud Computing, as it was mentioned during the discussion. However, edge computing still has a long way to become as ubiquitous as the Cloud is. Undoubtedly, both paradigms have a variety of benefits and use cases and can co-operate to deliver services in a vast difference. Nonetheless, it is currently up to the businesses to learn, accommodate and adopt the benefits of the Edge computing in order to accelerate its capacity and operations, while scaling down the usual risk factors. It was understood in the discussion that it is important to evidence that cloud and edge computing are different. That is, they are non-interchangeable technologies. On the one hand, edge computing is used to process time-sensitive data, while, on the other hand, cloud computing is used to massively process data that is not time-driven. Besides latency, edge computing is preferred over cloud computing in remote and potentially isolated locations, where there is limited or no connectivity to a centralized location. These locations require local storage, similar to a mini data centre, with edge computing providing the perfect solution for it. Finally, it was mentioned that edge computing is also beneficial to intelligent devices from the Federated Learning perspective. Intelligent devices can be involved in a collaborative manner to train and refine deep learning and machine learning algorithms, thus, materializing the vision of the distributed intelligence. However, a major challenge that was reported in the discussion is the nature of the distributed data, especially, *non-iid* complex data can hinder the federated training and modern methods have now started to elicit to tackle this problems (like federated personalized learning).

Question IV: *Where will AI fit into Edge Computing?*

The science of Artificial Intelligence could promote and help in evolving the edge computing paradigm; that was the lesson learnt from this question. Specifically, we are witnessing the advent of the IoT with numerous devices performing interactions between them or with end users. The huge number of devices leads to huge volumes of collected data that demand the *appropriate* processing. The 'legacy' approach is to rely on Cloud where increased computational resources can be adopted to realize any processing. However, even if the communication with the Cloud back end lasts for some seconds there are cases where problems in the network or the need for supporting real time applications require a reduced latency in the provision of responses/outcomes. Edge Computing enhanced by AI comes into the scene as the 'solver' of the latency problem. Any processing can be performed close to data sources, i.e., at nodes having direct connection with IoT devices. Hence, an ecosystem of processing nodes can be present at the edge of the network giving the opportunity to apply novel AI-led services *upon* the collected data. Various challenges should be met before we talk about a *fully automated ecosystem* where nodes can *understand* the status of them and the *environment* to be capable of efficiently serving end users or applications. We conclude on the evolving paradigm of Edge Mesh, which will act as a cover of the intelligence upon the edge computing infrastructure. Evidently, new theories adopted for data, tasks and resource management should be developed while we're discussing how deep machine learning and optimization techniques should be adopted to solve fitting computational intelligence into autonomous edge computing devices.

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