School of Computing, Engineering, and the Built Environment
Edinburgh Napier University

PHD STUDENT PROJECT

Application instructions:
Detailed instructions are available at :
https://www.napier.ac.uk/research-and-innovation/doctoral-college/how-to-apply

Prospective candidates are encouraged to contact the Director of Studies (see details below) to discuss the project and their suitability for it.

Project details

Supervisory Team:

- DIRECTOR OF STUDY: Dr. Amjad Ullah (Email: a.ullah@napier.ac.uk)
- 2ND SUPERVISOR: tbc

Subject Group: Computer Science

Research Areas: Computer Science (Software engineering, Machine Learning, Internet of Things, Distributed systems)

Project Title: AI-driven Cloud-to-Things application-level orchestration framework for next-generation Internet of Things systems

Project description:

The next generation of Internet-of-Things (IoT) systems is becoming an essential part of our day-to-day environment. Smart cities, smart manufacturing, augmented reality, industry 4.0, and self-driving cars are just some examples of the wide range of domains, where the applicability of such systems, is extremely impactful due to the fact that the huge amount of generated data could be used in order to train AI models to make dynamic reconfiguration decisions. Such systems have to deal with versatile requirements such as the need for high bandwidth, privacy sensitivity, and context awareness (e.g., time/location awareness) and simultaneously require access to geographically distributed arrays of sensors, remote localised computational resources of heterogeneous natures, as well as large-scale on-the-fly multi-cloud computational resources. The aforementioned requirements gave birth to a new computing model called the Cloud-to-Edge compute continuum –

where computation, storage, data management and decision-making occur along the path of edge devices closer to the source and the cloud.

The natural extension from the cloud model to the Cloud-to-Edge continuum has significantly increased the complexity of the orchestration of application services, where the orchestration solutions are now expected to operate in multi-administrative environments and have to deal with the associated challenges such as heterogeneity, volatile connectivity, mobility, liaise with system-specific contextual constraints, resource-constrained computational capabilities, volatile changing environment, versatile security threat scenarios, application performance monitoring at different levels, etc. The existing landscape of Cloud-to-Things orchestration includes solutions like (1) resource provider solutions such as Amazon GreenGrass, Microsoft's Azure IoT core and Google's Cloud IoT Core - suffer from vendor lock-in, (2) low-level infrastructure solutions such as KubeEdge, Kubefed - require low-level specific infrastructure knowledge or (3) reference architectures such as ENORM, Foggy - lack various essential building blocks such as specification layer, runtime reconfigurability, etc.

This PhD project aims to evolve the concept of Cloud-to-Edge orchestration towards developing a uniform vendor (and technology)-agnostic orchestration system, that facilitates the automated deployment and runtime management of next-generation intelligent IoT systems across the Cloud-to-Things ecosystem simultaneously using a single model-driven specification of the input system, and where the deployment and runtime reconfiguration decisions are driven by an intelligent context-aware engine. The key aspects of this project include:

1. Design of a high-level modular architecture for an application-level Cloud-to-Things orchestration framework,
2. Ensuring interoperability across different cloud (resource) providers,
3. Efficient connectivity and management of volatile Non-cloud (Fog/Edge) resources,
4. Integration of AI-driven context-aware mechanism to formulate run-time reconfiguration decisions,
5. Effective and secure coordination across the various building blocks of the system in the Cloud-to-Edge compute continuum.

References:

[1] Ullah, A., Kiss, T., Kovács, J., Tusa, F., Deslauriers, J., Dagdeviren, H., Arjun, R. and Hamzeh, H., 2023. Orchestration in the Cloud-to-Things compute continuum: taxonomy, survey and future directions. Journal of Cloud Computing, 12(1), pp.1-29.

[2] Ullah, A., Dagdeviren, H., Ariyattu, R. C., DesLauriers, J., Kiss, T., & Bowden, J. (2021). MiCADO-Edge: Towards an application-level Orchestrator for the Cloud-to-Edge Computing Continuum. Journal of Grid Computing, 19(4), 1-28.

[3] Yousefpour, A., Fung, C., Nguyen, T., Kadiyala, K., Jalali, F., Niakanlahiji, A., ... & Jue, J. P. (2019). All one needs to know about fog computing and related edge computing paradigms: A complete survey. Journal of Systems Architecture, 98, 289-330.

[4] Abowd, Gregory D., et al. "Towards a better understanding of context and context-awareness." International symposium on handheld and ubiquitous computing. Springer, Berlin, Heidelberg, 1999.

[5] Velasquez, K., Abreu, D. P., Assis, M. R., Senna, C., Aranha, D. F., Bittencourt, L. F., ... & Madeira, E. (2018). Fog orchestration for the Internet of Everything: state-of-the-art and research challenges. Journal of Internet Services and Applications, 9(1), 1-23.

Candidate characteristics

Education:

A second class honour degree or equivalent qualification in computer science

Subject knowledge:

- Software engineering
- Computer programming
- Cloud technologies
- Machine learning

Essential attributes:

- Experience in fundamental software engineering
- Competent in one (or some) programming languages
- Knowledge of Cloud, IoT and Microservices architecture
- Good written and oral communication skills
- Strong motivation, with evidence of independent research skills relevant to the project
- Good time management