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:

Subject Group: Computer Science

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

Project Title: Architecture for decentralising intelligence in dynamic cloud-fog-edge compute continuum

Project description:

AI-enabled IoT systems are becoming an essential and integral part of our daily lives. For example, systems like e-health, smart homes, and smart manufacturing have already demonstrated a huge impact. This breed of IoT applications raises challenges in regard to efficient data collection and processing strategies, location awareness, reliance on specific and heterogenous computational, adherence to complex data privacy and security objectives, compliance to the ability of IoT devices to provide quality service, social trust (ST) among the owners of IoT devices at different layers, and Low latency [1]–[3]. These challenges raise serious concerns in regard to the commonly used centralized cloud model for such systems. Hence, the dynamic compute continuum spanning across cloud-fog-edge infrastructure has emerged as the new promising model to support the requirements of on-demand access to a shared pool of configurable, heterogenous

and dynamic set of computational resources [4], that can be used for the execution of the next generation of IoT systems.

The coordinated management and optimization of these resources is the responsibility of an orchestration solution, which is usually governed by a set of deployment and runtime reconfiguration strategies [5]. These strategies must address the key versatile requirements of IoT applications that include but are not limited to, simultaneous access to a distributed set of resources, dealing with heterogeneity, high dynamicity, diversity of resource types and most importantly uncertainties (e.g., volatile connectivity, mobility etc.) of the underlying distributed environment [6], [7]. Furthermore, the structural topology of an application may also change due to the tasks' completion or changes in the executing environment [8], [9] such as changes in traffic patterns, and resource availability [10], [11]. In such a highly dynamic environment, resources and application components (micro-services) need to be deployed and reconfigured to ensure the uninterrupted execution of the IoT applications according to the system's stated QoS objectives. To deal with this highly dynamic and distributed nature of the compute continuum, existing centralized solutions, frequently suffer from scalability, latency, and privacy issues, while typical distributed methods fail in regard to the system's heterogeneity, variability, and uncertainty.

The objective of this research is to seek the development of new solutions based on the decentralisation of intelligence across a dynamic compute continuum. More particularly, this research will be the confluence of three key aspects: Use and retrieval of contextual information across the entire spectrum of the compute continuum, decentralizing architecture for distributing the execution of intelligence in the compute continuum, and use of ML techniques for decision making regarding application deployment, and reconfiguration.

References:

[1] L. Fotia, F. Delicato, and G. Fortino, “Trust in Edge-based Internet of Things Architectures: State of the Art and Research Challenges,” ACM Comput Surv, vol. 55, no. 9, pp. 1–34, Sep. 2023, doi: 10.1145/3558779.

[2] C. H. Hong and B. Varghese, “Resource management in fog/Edge computing: A survey on architectures, infrastructure, and algorithms,” ACM Comput Surv, vol. 52, no. 5, Sep. 2019, doi: 10.1145/3326066.

[3] J. Wang and L. Wang, “A Computing Resource Allocation Optimization Strategy for Massive Internet of Health Things Devices Considering Privacy Protection in Cloud Edge Computing Environment,” J Grid Comput, vol. 19, no. 2, Jun. 2021, doi: 10.1007/s10723-021-09558-y.

[4] P. Pradeep, S. Krishnamoorthy, and A. v. Vasilakos, “A holistic approach to a context-aware IoT ecosystem with Adaptive Ubiquitous Middleware,” Pervasive Mob Comput, vol. 72, Apr. 2021, doi: 10.1016/j.pmcj.2021.101342.

[5] O. Tomarchio, D. Calcaterra, and G. di Modica, “Cloud resource orchestration in the multi-cloud landscape: a systematic review of existing frameworks,” Journal of Cloud Computing, vol. 9, no. 1, Dec. 2020, doi: 10.1186/s13677-020-00194-7.

[6] D. Petcu, “SERVICE DEPLOYMENT CHALLENGES IN CLOUD-TO-EDGE CONTINUUM,” vol. 22, no. 3, pp. 313–320, 2021, doi: 10.12694:/scpe.v22i3.1941.

[7] L. Bittencourt et al., “The Internet of Things, Fog and Cloud continuum: Integration and challenges,” Internet of Things (Netherlands), vol. 3–4. Elsevier B.V., pp. 134–155, Oct. 01, 2018. doi: 10.1016/j.iot.2018.09.005.

[8] S. Svorobej, M. Bendechache, F. Griesinger, and J. Domaschka, “Orchestration from the Cloud to the Edge,” 2020, pp. 61–77. doi: 10.1007/978-3-030-41110-7_4.
[9] Z. Wen et al., “Fog Orchestration for Internet of Things Services,” 2017. [Online]. Available: www.computer.org/internet/
[10] T. Yeh and S. Yu, “Realizing dynamic resource orchestration on cloud systems in the cloud-to-edge continuum,” J Parallel Distrib Comput, vol. 160, pp. 100–109, Feb. 2022, doi: 10.1016/j.jpdc.2021.10.006.
[11] A. Mijuskovic, A. Chiumento, R. Bemthuis, A. Aldea, and P. Havinga, “Resource management techniques for cloud/fog and edge computing: An evaluation framework and classification,” Sensors, vol. 21, no. 5. MDPI AG, pp. 1–23, Mar. 01, 2021. doi: 10.3390/s21051832.

Candidate characteristics

Education:

A second class honour degree or equivalent qualification in computer science

Subject knowledge:

- 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