Dept. of Computer Science
Télécom SudParis
IP Paris, France

Internship Program 2024
Advancing AI-Driven IoT: Enabling Proactive Adaptation
of IoT Systems with Causal Discovery and Reinforcement Learning
October 27, 2023

Project Description

Context. The Internet of Things (IoT) has revolutionized the way we interact with our environment. Today's IoT environments consist of a complex infrastructure comprising IoT devices and sensors that sense physical phenomena and generate data. This data is further processed by virtual sensors to create enriched high-level observations, and various applications offer services to different stakeholders within these smart environments. However, ensuring the quality of these services, known as Quality-of-Service (QoS), is a critical challenge. QoS requirements, such as maximum latency, data accuracy, and location constraints, must be met to guarantee the correct behavior of IoT applications [1]. This is mainly caused by the complex and intricate interactions among the different components of the IoT systems.
The Challenge. IoT systems are dynamic by nature and changes may occur to the infrastructure deployed at runtime, leading to applications experiencing degraded QoS performance. For instance, some IoT devices may become unavailable because of low energy levels, or some applications might experience higher latency because of network link congestion or failure. To address these challenges, several approaches have been developed to propose adaptation strategies in response to possible changes [2, 3, 4, 5]. However, most of these approaches are reactive, meaning they respond to problems *after* they occur and QoS degrades. The primary challenge we address in this project is how to proactively adapt IoT systems to predict and limit potential QoS degradation *before* it impacts users.

Internship Objectives The primary objective of this internship is designing and developing an approach for proactive adaption of IoT systems. To achieve this, we will need first to understand the underlying interactions among the different IoT system components for discovering possible causes of QoS degradation. For this purpose, causal discovery methods [6, 7] will be used to analyze performance datasets of the system and extract existing dependencies in the IoT system. This will result in the creation of causal graphs that can be used to enrich the existing performance datasets. Then, a reinforcement learning agent will be trained using the enriched dataset to take actions to mitigate QoS degradation resulting from runtime changes.

Qualifications

Master 2 or last year of engineering school.

Skills & qualities

- Fluent in English
- Experience in developing machine learning models for accurate trend predictions.
- Experience with reinforcement learning techniques (e.g., Q-learning, SARSA).
- Knowledge of control models (e.g., MAPE-K) for autonomic and self-adaptive systems.
- A strong motivation for solving research problems.

Useful information

- Starting date: February 2024 (flexible)
- Duration:: 5-6 months
- Location: Télécom SudParis, Évry or Palaiseau

Contact

To apply, contact:

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by providing the following documents:

1. CV
2. Motivation letter
3. Transcripts of the last 3 years
4. A course report or article written in English (if any)

References and Additional Reading

[1] Houssam Hajj Hassan, Georgios Bouloukakis, Ajay Kattepur, Denis Conan, and Djamel Belaïd. Plan-iot: A framework for adaptive data flow management in iot-enhanced spaces. In *18th Symposium on Software Engineering for Adaptive and Self-Managing Systems (SEAMS)*, 2023.

[2] Henry Muccini and Karthik Vaidhyanathan. Leveraging machine learning techniques for architecting self-adaptive iot systems. In *2020 IEEE International Conference on Smart Computing (SMARTCOMP)*, pages 65–72, 2020.

[3] Cody Kinneer, Zack Coker, Jiacheng Wang, David Garlan, and Claire Le Goues. Managing uncertainty in self-adaptive systems with plan reuse and stochastic search. In *Proceedings of the 13th International Conference on Software Engineering for Adaptive and Self-Managing Systems (SEAMS)*, page 40–50, New York, NY, USA, 2018. Association for Computing Machinery.

[4] Jia Li, Shiva Nejati, and Mehrdad Sabetzadeh. Learning self-adaptations for iot networks: A genetic programming approach. In *Proceedings of the 17th Symposium on Software Engineering for Adaptive and Self-Managing Systems (SEAMS)*, pages 13–24, 2022.

[5] Majid Lotfian Delouee, Boris Koldehofe, and Viktoriya Degeler. Aqua-cep: Adaptive quality-aware complex event processing in the internet of things. In *Proceedings of the 17th ACM International Conference on Distributed and Event-based Systems (DEBS)*, pages 13–24, 2023.

[6] Zhizhang Hu, Tong Yu, Ruiyi Zhang, and Shijia Pan. Ciphy: Causal intervention with physical confounder from iot sensor data for robust occupant information inference. In *Proceedings of the 20th ACM Conference on Embedded Networked Sensor Systems*, SenSys '22, page 966–972, New York, NY, USA, 2023. Association for Computing Machinery.

[7] Yan Zeng, Ruichu Cai, Fuchun Sun, Libo Huang, and Zhifeng Hao. A survey on causal reinforcement learning, 2023.

[8] Fahed Alkhabbas, Ilir Murturi, Romina Spalazzese, Paul Davidsson, and Schahram Dustdar. A goal-driven approach for deploying self-adaptive iot systems. In *2020 IEEE International Conference on Software Architecture (ICSA)*, pages 146–156, 2020.