Université de Rennes

Appel à projets - Année 2025

Contrats doctoraux «Ordinaires»

Direction de la Recherche et de l'Innovation

ECOLE DOCTORALE : MATISSE **POLE DE RECHERCHE : Mathématiques-Numérique**

Unité de recherche d'accueil

Unité de Recherche : IRISA

Equipe : ERMINE

Encadrement

Directeur de thèse : Bruno Sericola **Unité de recherche** : IRISA

Employeur/Établissement d'origine : Centre Inria de l'Université de Rennes

HDR : ■ oui • non **Nb de thèses en cours** : 0

Mail : bruno.sericola@inria.fr **Tél**. :+33 2 99 84 72 97

Co-directeur de thèse : **Unité de recherche** :

Employeur/Établissement d'origine :

HDR : • oui • non **Nb de thèses en cours** :

Mail : **Tél.** :

Sujet

Titre : ***Resilient AI-Based for Radio Access Networks Beyond 5G***

Mots clés : cell outage compensation, cell coverage optimization, cellular traffic engeneering, multi-agent systems, reinforcement learning, deep Q-Network

Cotutelle internationale (oui/non) : non **Si oui, préciser l'établissement et le pays de rattachement** :

Descriptif (15-30 lignes) :

Contexte socioéconomique et scientifique ; Les hypothèses et questions posées ; Les grandes étapes de la thèse et démarche ; Approches méthodologiques et techniques envisagées

1. General context

The upcoming post-5G networks are expected to deliver ubiquitous broadband access for an enormous number of connected devices. It constitutes highly complicated environment including cutting-edge technologies, such as massive IoT, edge computing, and network slicing. 6G networks are supposed to accommodate extremely diverse use cases ranging from ULLR services that need ultra-low latency and reliability, such as autonomous driving and remote surgery, to high-throughput services that prioritize large data transfer, and broadcast service systems focused on distributing media to a wide audience. This entails a tangled and confusing ecosystem requiring considerable and costly management processes where conventional human-led solutions have reached their limits. To solve that major issue, AI has been suggested as alternative [1].

2. Goals and Challenges

In earlier network generations, humans can still maintain control over the management process. Actually, leading network operators are still performing human-operated management in order to manage their transport infrastructure. This strategy is approaching its limits and is unlikely to effectively handle the growing dynamic, scale, and complexity of future networks. In such a case, adopting AI-based management processes offers an appealing and, to some extent, inevitable alternative. That is why, we aim in this work to develop an AI dedicated to perform customized cells management in order to improve radio cell resiliency and efficiency. This specialized AI is expected, among others, to improve network availability, accelerate recovery from failures and enhance User Experience. This proposal includes the following challenges that should be addressed :

Challenge 1*: Data quality and availability*

Building robust and unbiased AI-based solutions rely heavily on large volumes of high-quality data. This requires understanding the nuts and bolts of real post-5G cellular network in order to assess the available data and explore its underlying features and relationships. A compromise should be found that balances the data collection cost with its relevance.

***Challenge 2**: AI model selection and training*

Since AI is not a one-size-fits-all solution, a considerable work should be made in order to find the suitable AI for each management operation, e.g., resource allocation, fault recovery and load balancing. This modeling phase should account for data characteristics and operational constraints. In our case, we will mainly focus on radio cell failure management using Multi-Agent Deep Reinforcement Learning (MARL), which is presumed as one of the most promising techniques for such a context.

***Challenge 3**: AI deployment and post-deployment*

The AI deployment over radio cell is a crucial aspect that should be addressed. The deployment strategy should account for AI prerequisite in addition to several operational criteria such as latency, resource availability, and scalability. Moreover, it is required to foresee in which way the AI should evolve in order to follow varying network and traffic conditions.

3. Work plan

- Dissect post-5G radio cell architecture in order to understand its key components and underlying protocols. A priority task will be given to catalog all sources of information that can be likely used for management operation.
- Propose an efficient and impartial measurement methodology to gather relevant and accessible metrics. This procedure should incorporate both passive and active measurement techniques, which can be triggered based on timers or specific events.
- Conduct both inter- and intra-data analysis on the collected radio cell dataset across different time frames and scales. This involves conducting Exploratory Data Analysis (EDA) to better understand the dataset and uncover patterns or insights. Next, model selection and training will be carried out for each management operation, tailored to its specific requirements. As previously stated, priority will be given to multi-agent learning models.
- Develop advanced strategies that facilitate sustainable AI deployment and ensure effective post-deployment management in radio networks beyond 5G.

Note:
This thesis extends prior collaborative work between Inria and Nokia, aiming to study and quantify resiliency within the context of post-5G cellular radio networks [2] [3].