XAInomaly: Explainable, Interpretable and Trustworthy AI for Next Generation Ultra-reliable Low-latency Communications (xURLLC) in 6G Networks

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Abstract

6G networks are designed to support mission-critical applications, such as remote healthcare services, autonomous vehicles, AI-guided industrial automation, and the tactile internet, all of which rely on xURLLC. Ensuring network reliability in these contexts requires robust anomaly detection mechanisms that can proactively identify and address potential disruptions. However, traditional AI/ML-based anomaly detection systems often lack interpretability, creating barriers to trust and adoption. To address this, we propose a novel reactive Explainable AI (XAI) framework tailored for real-time anomaly detection in 6G networks.

Introduction

The rapid evolution of 6G networks introduces a new frontier for critical applications that demand unprecedented levels of reliability and low latency (Saad, Bennis, and Chen 2020; Bohlin, Cappelletti, and Nestoras 2022). These applications, ranging from real-time healthcare diagnostics to autonomous vehicle coordination, rely on the seamless operation of complex, highly dynamic network infrastructures. However, the heterogeneity and dynamic nature of 6G networks make them susceptible to anomalies that can compromise performance and reliability. Proactive detection of such anomalies is vital to maintaining the integrity of critical systems. Anomaly detection systems powered by AI/ML models have shown promise in identifying deviations from normal network behavior. But their opaque nature is particularly concerning in telecom-based mission-critical infrastructure (transportation, tactile internet, industrial automation and smart energy management systems), where understanding the cause of an anomaly is as important as resolving it. XAI addresses this challenge by providing insights into the reasoning behind AI decisions, enabling operators to trust and act upon AI-driven anomaly detection with confidence. In this context, integrating XAI into 6G networks is not merely a technical challenge but a societal imperative (Guo 2020). Transparent decision-making ensures compliance with safety regulations, facilitates efficient resource allocation, and supports the equitable management of telecom-critical infrastructures.

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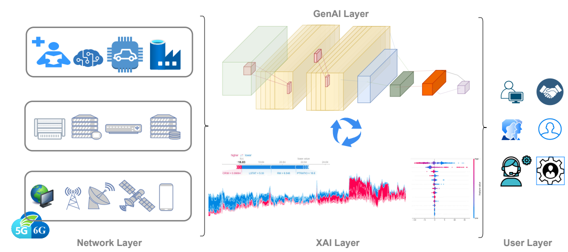

Figure 1: Our GenAI and XAI design between user and critical infrastructure

Proposed Design: XAInomaly Framework

Considering aforementioned challenges, to ensure that the AI/ML algorithms used in 6G networks are trustable and reliable, we proposed a `XAInomaly` framework that use our novel `fastSHAP-C` method which handle real-time XAI layer operations (Basaran and Dressler 2024) [1] as shown in Figure 1. Our framework integrates a Deep Autoencoder model for detecting anomalies while utilizing our proposed `fastSHAP-C`, a model-agnostic XAI method, to provide transparent insights into the decision-making process. This approach ensures reliability, interpretability, and low-latency performance, positioning XAI as a cornerstone for managing critical infrastructure in 6G networks. In our experiments, performance gains with `fastSHAP-C` are more pronounced on high-end servers with more cores. This presents that `fastSHAP-C` is optimized to take full advantage of multi-core architectures, making it highly scalable for large datasets and complex models that require parallel processing. Overall performance results show that `fastSHAP-C` provides 25% advance over its competitors in terms of resource utilization.

Conclusion

The integration of XAI into 6G and beyond (i.e., next-generation wireless networks) is a game-changer for critical infrastructure systems. Our `XAInomaly` framework, exemplifies this vision by optimizing resource utilization and providing real-time explainability for time-critical applications.

[1] Presented in IEEE 6GNet Conference 2024. Technical Details: https://www.tkn.tu-berlin.de/bib/basaran2024xainomaly/

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