Federated Learning of Explainable Artificial Intelligence Models: A Proof-of-Concept for Video-streaming Quality Forecasting in B5G/6G networks*

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Abstract

The next generation of mobile networks is poised to rely extensively on Artificial Intelligence (AI) to deliver innovative services. However, it is crucial for AI systems to fulfill key requirements such as trustworthiness, inclusiveness, and sustainability. Starting from these requirements, we proposed Federated Learning of eXplainable AI (Fed-XAI) models within the Hexa-X EU Flagship Project for 6G. This paper focuses on the implementation of a real-time testbed, serving as a proof of concept for the Fed-XAI paradigm. The testbed utilizes genuine applications and real devices that interact with a mobile network, emulated using the Simu5G simulator. Its primary objective is to provide explainable predictions regarding video-streaming quality in an automotive scenario.

Keywords

Federated Learning, Explainable Artificial Intelligence, B5G/6G Mobile Networks, Video Streaming Quality Prediction

1. Demo Description

The Hexa-X project[1], which is funded by the European Union (EU) under the Horizon 2020 program, serves as the flagship initiative for advancing Beyond-5G (B5G) and 6G systems. Trustworthiness is a crucial aspect of future mobile communication systems, as Artificial Intelligence (AI) techniques are expected to support various services in B5G/6G networks [1]. Within the Hexa-X project, the University of Pisa, in collaboration with Intel and TIM, has been engaged in activities related to Federated Learning (FL) of eXplainable AI (XAI) models, referred to as Fed-XAI. Fed-XAI enables the development of trusted and ethical next-generation

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networks by training AI models in a distributed and privacy-preserving manner through FL, while ensuring transparency through XAI [2]. The activities related to Fed-XAI in the Hexa-X project mostly include:

- Developing strategies for FL of inherently explainable models, such as rule-based models [3];
- Designing a communication framework that enables users in the B5G/6G network to access FL services through the as-a-service paradigm, while offloading computationally intensive tasks like model training to Multi-access Edge Computing (MEC) systems [4].

It is worth noticing that Fed-XAI has been recognized as a key innovation by the EU Innovation Radar[2].

To validate the algorithms and the communication framework developed within the project, a Proof-of-Concept (PoC) has been implemented. The PoC consists of a real-time testbed comprising actual devices and a mobile network emulator. The aim of the PoC is to demonstrate the benefits of building XAI models in a federated manner, with a specific focus on an automotive use case. Tele-operated driving (ToD) is one of the innovative services envisioned in 6G systems, where connected cars transmit real-time video streams of the driver's perspective to a remote driver situated at the network edge [5]. The remote driver, whether human or machine, can control the car by sending commands based on the received video stream. The smoothness and quality of the video stream are critical for safe ToD, and therefore it becomes crucial to be able to predict any fluctuations in advance. Fed-XAI facilitates this forecasting service by leveraging the collaborative training of XAI models using data from multiple cars, while providing meaningful explanations for the predictions.

The PoC consists of an offline training phase, where a large dataset of Quality of Service (QoS)-related data is generated using Simu5G simulator [6]. The dataset includes metrics from video-streaming sessions in an urban network scenario involving cars transmitting video streams to an edge application. The training dataset, comprising three days' worth of data, is used to train an explainable by design AI model for regression task, namely a Takagi-Sugeno-Kang Fuzzy Rule-Based Systems (TSK-FRBSs), within an FL setting [7]. To support both the learning and the inference processes, we designed and developed a Fed-XAI application [8] which can be deployed on edge computing environments, utilizing a fully-virtualized architecture and containerization for portability and ease of migration in real-world scenarios. The Intel OpenFL library[3], extended to support FL of explainable by design models such us TSK-FRBSs, has been exploited for the implementation of FL services offered by the designed application.

Figure 1 depicts the design scheme of the proposed testbed for the online inference phase. The testbed has been then actually implemented for a working real-time: as shown in Fig. 2, it includes a mini PC running Simu5G [9] to emulate the mobile network, a video server transmitting the video stream and a video player hosted on a laptop and a tablet, respectively.

The Fed-XAI application has been deployed on a workstation running an instance of the Docker Engine for light virtualization by means of containers [10]. The video packets generated by the video server traverse the emulated network before reaching the video player, allowing

[2] https://www.innoradar.eu/innovation/45988
[3] https://openfl.readthedocs.io/en/latest/

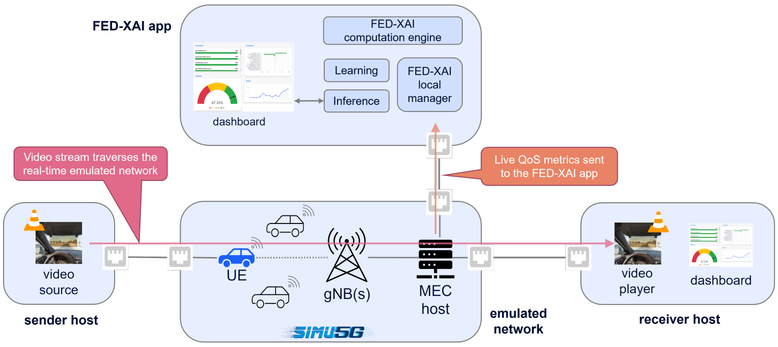

Figure 1: Scheme of the testbed of the Fed-XAI PoC

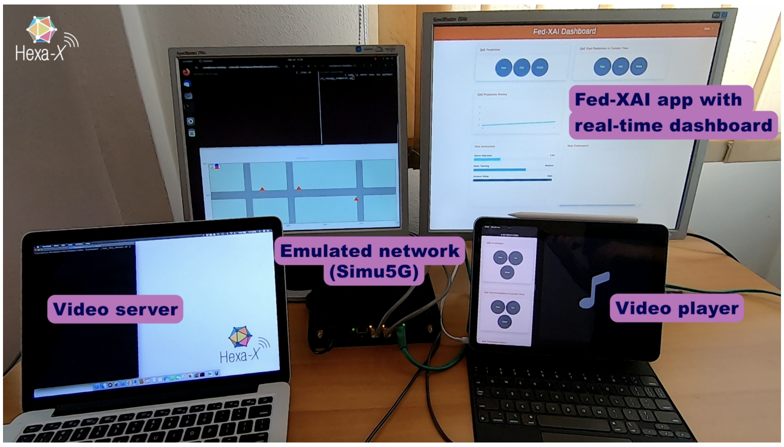

Figure 2: Real Proof-Of-Concept Implementation

the assessment of video quality based on network conditions. Probes within Simu5G provide QoS real-time metrics for the inference module of the Fed-XAI application, which utilizes the pre-trained model to make quality predictions. These predictions, along with their explanations, are displayed in real-time on the Fed-XAI dashboard. Specifically, the dashboard visualizes the predicted level of the video quality for the next three seconds and verifies the accuracy of predictions made three seconds prior, along with the last 15 predictions and the rule that triggered the current prediction. The testbed demonstrates the effectiveness of the Fed-XAI approach, as depicted in the Fed-XAI application dashboard. As an example, Fig. 3 showcases the prediction of a bad video quality and its explanation, taking into account factors like high cell load utilization and low signal-to-interference-plus-noise ratio experienced by the car.

2. Expected contribution to the XAI community

The Proof-of-Concept shows the advantages of building XAI models in a federated fashion. In particular, we focused on an automotive use case, namely tele-operated driving. The PoC

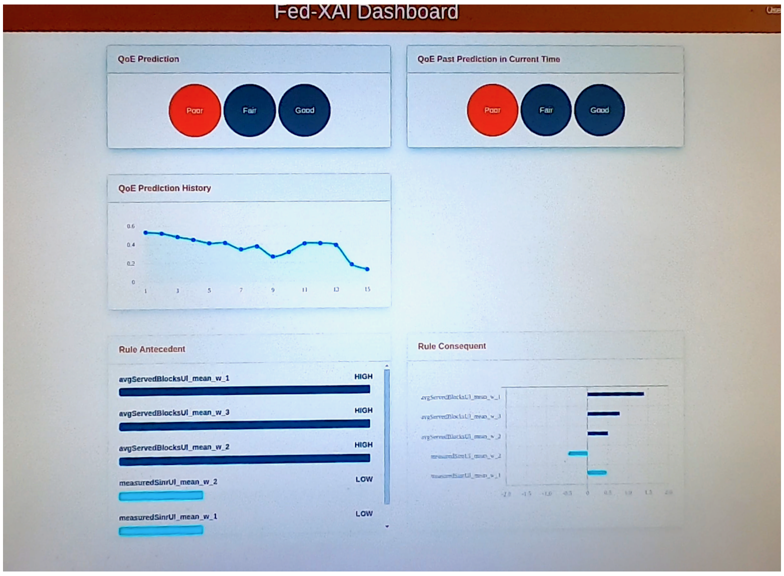

Figure 3: A Snapshot of the Fed-XAI Dashboard

involved two main phases: i) offline FL of XAI models using Quality of Service data generated by a mobile network simulator (Simu5G) and ii) implementation of a real testbed built with real components. These components include a video server and video player, an instance of Simu5G to emulate the video stream through the mobile network, and an instance of the Fed-XAI application to perform actual predictions and show explanations of decisions made. The testbed demonstrates the effectiveness of the Fed-XAI approach in predicting video quality and providing meaningful explanations based on real-time network conditions. The activity fits into an area of research at the interface between XAI and decentralised ML, which has not been exhaustively investigated so far.

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