6GxAID: Integrating 6G Networks and eXplainable Artificial Intelligence for Drone-Based Assistance in Emergency Situations

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Abstract

Explainable Artificial Intelligence (xAI) encompasses a set of techniques to make AI model decisions more transparent and interpretable for humans while promoting transparency and trust. By leveraging emerging xAI techniques to improve the use of the 6th Generation (6G) networks for critical applications, particularly drone-based assistance in emergency scenarios, a novel scheme called 6GxAID is proposed. The proposed scheme is validated through a telemedicine use case for diabetes management, where drones operate in resource-constrained environments and rely on satellite backhaul for data transmission in areas with limited terrestrial network coverage. By adopting SHapley Additive exPlanations-based xAI methods, the proposed scheme enables effective feature selection to minimize the size of transmitted data while maintaining high learning accuracy. This approach optimizes energy efficiency for resource-constrained devices and reduces satellite bandwidth consumption, ensuring reliable and scalable operations during emergencies.

Index Terms

6G Networks, explainable Artificial Intelligence (xAI), Drone-based Assistance, Unmanned Aerial Vehicle (UAV), Next-generation networking

I. Introduction

Artificial Intelligence (AI) will be natively and pervasively integrated into 6th Generation (6G) networks [1], by driving unprecedented levels of intelligence and adaptability through fully AI-based automation, Zero-touch network and Service Management (ZSM), and Network Digital Twin (NDT) paradigms, and cross-domain orchestration and management in integrating Terrestrial Networks (TNs) and Non-Terrestrial Networks (NTNs) [2]. However, the stringent and new Key Performance Indicators (KPIs) and requirements of 6G together with the inherent opacity of AI-driven processes represent critical challenges in the 6G architecture design [3]–[6].

To address these limitations, explainable Artificial Intelligence (xAI) is emerging as a promising solution for the integration into 6G networks [6]. xAI allows to overcome traditional "black-box" issues of AI mechanisms, by contributing to fostering trust, reaching security, and preserving privacy through clarifications of network behaviors. Simultaneously, its explainability facilitates the development of novel strategies and algorithms to reduce data to be processed and to optimize the usage of communication and computational resources. This fits perfectly to the sensing devices that collect data, e.g., medical sensors and healthcare wearable devices [7], [8], often very small and with limited resources. For instance, xAI can play a pivotal role at the network edge in reducing the volume of data collected by sensing devices and minimizing the data offloaded to the cloud, without affecting the performance. Additionally, xAI can be strategic to revolutionize digital healthcare (eHealth) while safeguarding sensitive data, in compliance with regulatory frameworks and dimensions of eHealth [9].

Drones or Unmanned Aerial Vehicles (UAVs) are increasingly adopted in several applications and widespread towards the 6G integration of TNs and NTNs for ubiquitous, resilient, and 3-dimensional (3D) wireless infrastructure [2], [10]. The role of drones can be pivotal in providing assistance in emergency situations, including scenarios related to telemedicine for telediagnosis, screening campaigns, and teleconsultations where people's lives are at stake or in drastic situations related to remote or disaster zones where data to be sent over the satellite backhaul need to be filtered due to low bandwidth [11]. Thus, only urgent or prioritized data—such as medical alerts, real-time disaster sensor data, or emergency communications—should be transmitted over the satellite link, optimizing its bandwidth and reducing power consumption.

In line with these emerging trends, we propose and preliminarily investigate the integrating 6G Networks and explainable Artificial Intelligence for Drone-Based assistance in emergency situations (6GxAID) scheme. As the name suggests, it considers 6G networks as a huge opportunity to be used as an "AID" in critical and emergency situations, such as telemedicine and disaster, by integrating xAI for Drone-based assistance.

In order to preliminarily validate the effectiveness of 6GxAID, which integrates xAI in all 6G network layers [6], [12]–[15], we consider a telemedicine use case related to diabetes. We adopt a well-known xAI method, i.e., SHapley Additive exPlanations (SHAP) [5], [6], for xAI-aided data collection and offloading also through satellite backhaul, as an alternative to

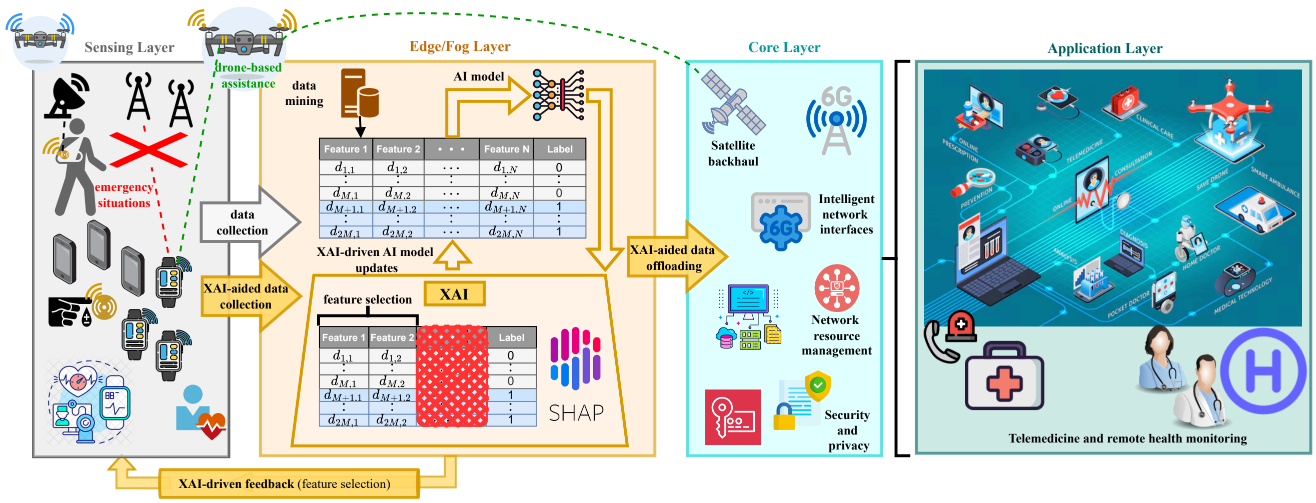

Fig. 1. The 6GxAID scheme applied to a telemedicine and remote health monitoring use case.

TNs especially in emergencies. The first aspect on data collection represents an advantage for resource-constrained sensors, while the second on data offloading is fundamental for resource limitations of drones and satellite backhaul capacity, offering lower bandwidth and making it crucial to minimize data transmission. The selection of features driven by SHAP through the first/first three most relevant features jointly leads to efficient classification performance and resource usage, allowing the loss of a negligible percentage in accuracy compared to the advantage of data size and energy efficiency.

The remainder of the paper is as follows. Section III is dedicated to the proposed 6GxAID scheme, while Section IV preliminarily demonstrates its effectiveness. Finally, Section V concludes the paper and draws future research activities.

II. The Proposed 6GxAID Scheme

The xAI-powered 6G architecture adopts a forward-looking approach to next-generation networks by harmoniously combining AI, xAI, and traditional network functions. This architecture is structured around four fundamental layers, which are tailored to enhance data handling, communication and computational resource optimization, intelligent decision-making, and overall system trustworthiness [1], [6]. We propose the 6GxAID scheme, visioning xAI integration in 6G networks for drone-based assistance as an ”AID” for emergency situations. In the context of TNs and NTNs integration towards 6G, the role of drones in 6GxAID scheme is crucial. While drones have become increasingly sophisticated, they face several limitations that make them resource-constrained, including battery life, processing power, data storage, and weight and dimension [16]. Given these limitations, drones require efficient data transmission and low-power operations. Free Space Optics (FSO)-based drones could also be combined to provide flexible, reliable, and high-speed communication systems [17]–[21]. In particular, in addition to providing wireless connectivity in infrastructure-lacking areas, FSO can be employed as the backhauling solution to significantly enhance the capacity of the backhaul link between ground base stations and drones. The optical beam from the base station serves a dual purpose: delivering both data and energy to the drone, thus enabling simultaneous communication and in-flight charging [18], [19].

By integrating xAI methods at the network edge, the 6GxAID scheme enables the identification of critical features for explainable monitoring and screening of emergency conditions, by facilitating selective and efficient data processing and transmission for resource-constrained devices, such as wearable devices and drones, and reducing the complexity of AI models while optimizing network performance and operations. Moreover, for emergencies where TNs are unavailable, satellite communication provides the necessary backhaul, with low-bandwidth satellite links that are used to transmit filtered and prioritized data from drones.

Fig. 1 depicts the proposed 6GxAID scheme for telemedicine and remote health monitoring.

As the network’s interfaces with the environment, the sensing layer collects data from diverse sources, such as wearable medical devices and sensors in remote monitoring setups. Examples of simple diabetes and heart rate medical devices (including smartphones or smartwatches) for continuous health monitoring (e.g., heart rate, blood pressure) are represented [7], [8]. xAI-driven feedback optimizes data collection (i.e., $d_{i,j}$ with i row/sample index and j column/feature index) by selecting only critical features for transmission. This targeted approach conserves energy and reduces bandwidth usage, which is decisive for devices with limited power resources. For instance, wearable devices can prioritize transmitting critical patient vitals while discarding non-essential data, ensuring timely and efficient communication in telemedicine. Analogous consideration can be

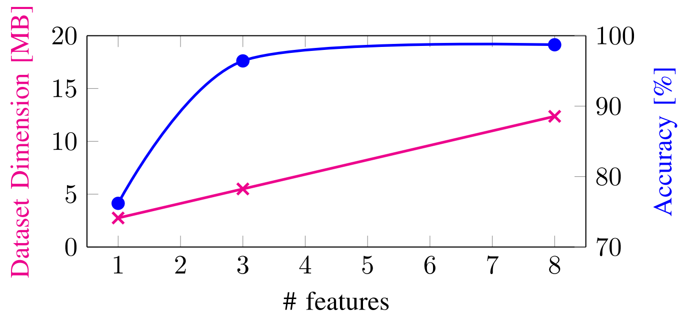

Fig. 2. Dataset dimension and Accuracy vs number of features in the dataset with a focus on the *Baseline* approach (8 features) and the proposed xAI-driven feature selections *SHAP-1 feature* and *SHAP-3 features*.

done for drones, which are power and bandwidth limited [22]. They intervene for assistance in emergency scenarios, by operating in resource-constrained environments and utilizing satellite backhaul for data transmission in areas with limited TN coverage. In fact, drones act as mobile sensors, capable of collecting data and covering large areas, especially in environments where traditional infrastructure may not be available (e.g., disaster zones, rural areas). They can process data (already limited in collection by sensors) at the edge and transmit only relevant information (via xAI-based filtering) to reduce bandwidth usage and optimize energy consumption.

The edge/fog layer processes data locally, enabling real-time analysis and decision-making close to the data source. xAI methods enhance feature selection, ensuring that only the most relevant medical data, such as urgent diagnostics or abnormal vitals, is transmitted to higher layers. These optimizations reduce transmission delay and computational load, which is essential for low-power devices in telemedicine ecosystems.

The core layer manages decision tasks as resource allocation, network slicing, and traffic control. This is typically done through high-bandwidth terrestrial or satellite communication. Data that requires further analysis, such as critical disaster-related information, may be sent via satellite backhaul, ensuring long-range communication in remote or disaster-stricken areas where traditional communication infrastructure is unavailable.

Finally, at the application layer, the xAI-enhanced 6G scheme demonstrates its full potential by enabling telemedicine and remote health monitoring, reducing bandwidth and energy usage while maintaining data integrity and trustworthiness.

III. Preliminary results

For preliminary analysis, a well-known and simple learning method, i.e., Random Forest [9], is applied to perform diabetes classification on a publicly available dataset[1] and then SHAP-based xAI methods [5], [6] are adopted. To highlight advantages deriving from xAI integration in 6G networks, the vertical cuts, i.e., feature selection, of the dataset on the basis of the most important features are considered. In particular, other than the case with the complete dataset, denoted with *Baseline*, the cases with the first most relevant feature (i.e., *HbA1C)*, denoted with *SHAP-1 feature*, and the first three relevant features (i.e., *HbA1C*, *glucose*, and *age*), denoted with *SHAP-3 features*, emerged through SHAP are considered. Thus, the new versions of the dataset contain the same number of samples (i.e., rows identified with the index i) but a reduced number of features (i.e., columns identified with the index j), by keeping only the first/first three most relevant ones other than the class label column. Fig. 2 shows the dimensions of the new versions of the dataset as a function of the number of the considered features. They are reduced with respect to the complete dataset: the dataset dimensions for *Baseline* (8 features), *SHAP-1 feature*, and *SHAP-3 features* are 12.37 MB, 2.75 MB, and 5.50 MB, respectively.

Fig. 2 also reports the classification performance (in terms of accuracy percentage) for the *Baseline*, *SHAP-1 feature*, and *SHAP-3 features* cases by adopting the same Random Forest model. The achieved values of accuracy are 98.71%, 76.20%, 96.42% for *Baseline*, *SHAP-1 feature*, and *SHAP-3 features*, respectively. It is possible to note that the case with the smallest dataset is obviously the one with one feature (*SHAP-1 feature*), while the case with the best classification performance is the one with all the features, i.e., *Baseline*. However, the case with the three most relevant features (*SHAP-1 feature*) loses only about 2%, in the face of data savings of almost 50% (precisely 44.46%). Therefore, the communication and computation resource savings deriving from the xAI-based vertical cuts do not affect learning performance. In particular, *SHAP-3 features* is an excellent compromise to save resources in terms of storage, processing, transmission time, bandwidth consumption, energy efficiency, learning complexity, and learning performance.

[1]https://www.kaggle.com/datasets/iammustafatz/diabetes-prediction-dataset?resource=download

IV. Conclusion and Future Directions

This paper introduced 6GxAID, a scheme that applies explainable AI (xAI) methods to enhance 6G networks for critical applications, focusing on drone-based assistance for telemedicine in emergency scenarios. The scheme uses SHAP-based xAI for reliable feature selection, minimizing transmitted data size and energy consumption in line with the requirements of resource-constrained devices, such as medical sensors and drones, while preserving learning accuracy and network conditions and coverage, also in emergencies through satellite backhaul technology. A practical study related to diabetes has preliminarily demonstrated the effectiveness of 6GxAID. Further investigations will analyze and quantify in detail the benefits of using the 6GxAID scheme in terms of resource savings. Moreover, Free Space Optics (FSO)-based drones will be explored to provide communication ecosystems with enhanced capabilities and resilience.

Acknowledgment

This work was supported by the European Union under the Italian National Recovery and Resilience Plan (NRRP) of NextGenerationEU, Mission 4, Component 2, in the context of “Telecommunications of the Future” (PE00000001 - program “RESTART”, CUP: D93C22000910001), integrated system of “Research and Innovation Infrastructures” (IR0000036 - program ”BRIEF”, CUP: J13C22000400007), national center on “Sustainable Mobility” (CN00000023-program “MOST”, CUP: D93C22000410001), partnership on “Cybersecurity” (PE00000007 - program “SERICS”, CUP: D33C22001300002, project ISP5G+), and National Plan for Complementary Investments in the context of ”D34Health” (PNC 0000001, CUP: B53C22006170001). It was also supported by the PRIN projects INSPIRE (grant no. 2022BEXMXN 01) and HORUS (grant no. 2022P44KA8) funded by the Italian MUR and by the HORIZON MSCA project BRIDGITISE (grant no. 101119554).

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