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**Perspective—6G and IoT for Intelligent Healthcare: Challenges and Future Research Directions**

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**ABSTRACT**

**success of 6G technologies and applications. Using these concepts, we explore the dependability of 6G networks in this article. Due to the vital role of machine learning in 6G, the dependability of federated learning, as a distributed machine learning technique, has been studied. Since mission-critical applications (MCAs) are highly sensitive in nature, needing highly dependable connectivity, the dependability of MCAs in 6G is explored. Henceforth, this article provides important research directions to promote further research in strengthening the dependability of 6G networks.**

**Keywords: 6G; dependability; security; reliability; availability; safety; communication networks**

### 1. Introduction

Fifth-generation wireless networks brought innovative technological concepts into the wireless domain that closed the gap between traditional IT domains and communication networks. For example, cloudification and softwarization of networking technologies enabled deploying new use cases and applications in wireless networks. Technologies from the physical layer, such as massive multi-input multi-output (MIMO), to the application layer, such as machine learning (ML) technologies, have increased networks’ capacities and capabilities. However, 5G cannot meet the requirements of emerging services such as the Internet of Everything (IoE), due to the inherent limitations of 5G systems [1]. Sixthgeneration communications networks will take a huge leap beyond 5G in order to meet the needs of future services and societies, which will be centered around data centric, intelligent, and automated processes [2]. Novel disruptive technologies in the domains of terahertz and optical communications, cell-less coverage through integrated terrestrialsatellite access technologies [3], distributed end-user terminal-based artificial intelligence (AI) [4,5], and distributed ledger technologies (DLTs) [6], to name a few, will converge to fulfill the needs of emerging applications and use cases [7].

Furthermore, 6G is expected to ignite a human transformation, thanks to improved context-aware devices with new human–machine interfaces provided by end-devices that are no longer mere data collectors, but multiple synchronized entities working in unison. This will dramatically improve the way we interact with both the physical and digital worlds. Such services will have have stringent quality of service (QoS) requirements in terms of bandwidth, reliability, and latency that will be challenging for existing 5G networks to provide. For example, ubiquitous and universal computing with resources distributed locally and in the cloud, knowledge systems that store and convert data into actions, and efficient sensing for controlling the physical world cannot be provided in 5G, and thus, focus is put on 6G research. Sixth-generation networks are also envisioned to provide massive-scale connectivity, 3D networking, real-time immersion through extended reality (XR), and haptic applications [8].

To stand on the envisioned promises, 6G must be highly distributed to meet the needs of latency, reliability, and availability of critical services, such as industrial automation systems, UAVs, and autonomous systems. Distributed clouds—edge, fog, and cloudlets [9]—will play a crucial role in providing the necessary computing and storage resources for distributed 6G. Softwarization of network functions and services will enable distributing important services to different network perimeters. Similarly, distributed AI in the distributed network will overcome challenges related to latency, reliability, data criticality, and privacy in 6G [10,11]. However, the distributed nature of the network will also create several challenges, mainly related to dependability. Therefore, in this article we discuss the dependability of 6G. Dependability, as discussed in detail in Section 3, ensures the trusted delivery of services.Elaborate discussion on dependability and its concepts is presented in [12], and thus we avoid writing in detail about dependability itself. In this article, we discuss the dependability of 6G from the systems engineering perspective, where the focus is laid on four well-known concepts: reliability, availability, security, and safety.

Reliability is the probability of a system working correctly for a certain period of time. As 6G networks will be highly distributed, the main concern regarding reliability is effectively coordination of the computing nodes. In order to achieve this, successful communication protocols between those computing nodes are needed, along with a reliable underlying network capable of supporting the amount of traffic generated by storing and retrieving data [13]. Availability refers to the probability of a system working properly at any given time. Distributed AI solutions for 6G networks are an attractive option for improving learning time while reducing resource consumption, and thereby improving the availability of AI-based systems and services. Form factor is an important variable, since it limits the resources, including energy, available for communication with external, distributed solutions. Security refers to capacity of a system for protecting itself by promptly identifying threats, and taking actions that effectively protect the services deployed on the system and data exchanged among the components and users. In the case of 6G network services, distributed AI/ML algorithms are needed to train models locally for threat identification and mitigation, in order to preserve the end user information. Finally, safety refers to the ability of a system to avoid harming human life, the environment, or private property. Since 6G networks will leverage use cases where human life is at the stake such as autonomous driving, it is in our interest to analyze the role of AI/ML in such situations.

In this work, we study the dependability of 6G networks in four dimensions, i.e., reliability, availability, safety, and security. We also analyze how the distributed nature of 6G networks negatively affects their dependability. Furthermore, we dive into the roles of distributed AI techniques and distributed mission-critical applications (MCAs) that are currently used in the intelligentization of the networks. We bring forth important challenges

with potential solutions and shed light on interesting future research directions. Henceforth, this article is organized as follows: Section 2 highlights the related work and contributions of this article. Section 3 briefly discusses the concept of dependability. Section 4 discusses dependability in 6G networks. Section 5 briefly introduces the AI techniques expected to be deployed on 6G edges, and their effects on dependability. Section 6 provides insights into the relation between dependability of MCAs in 6G. Interesting future research directions are summarized in Section 7, and the article is concluded in Section 8.