

6G in Developing High-Fidelity Immersive Digital Twins

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Abstract

Digital twins (DTs) (i.e., digital replicas/mirrors), with the main components i) a physical entity, ii) a virtual paired representation of that entity, and iii) bidirectional real-time seamless data streaming between these two entities with two-way communication, have changed the way of procedures in each discipline. The development of high-fidelity DTs, enabling the virtual entity to exist simultaneously with the physical entity, is imperative in many fields (e.g. healthcare DTs, smart city DTs, the metaverse (3D elevation of linear Internet) DTs, avatar DTs, and traffic DTs) in enhancing the efficacy of live systems, leading to increased Quality of Life (QoL) with high immersive Quality of Experiences (QoE). High-fidelity immersive DTs require the seamless integration of two main components of DTs - physical twins (i.e., virtual scale models) and live data twins of these physical twins. 5G communication technologies, with ultra-reliable low-latency communication (URLLC) abilities with ultra-high throughput, help the development of quality DTs in numerous fields. However, delays in data transfer and processing of data (e.g. for decision-making) affect the liveliness of DTs and affect their expected performance dramatically.

6G communication technologies, at the expense of increased complexity, consider not only delivering another 1000x increase in data rates, but also diving into self-sustaining networks and dynamic resource utilisation; 6G will also put an end to smartphone-centric networks, introducing new system paradigms (e.g., human-centric services). 6G, not only promises to connect things with URLLC (1-microsecond latency) leading to no delay in real time, but also promises to connect things intelligently with ultra-high-density connections (i.e., over 100 devices per cubic metre). In this sense, the use of location awareness immersive technologies, AR/VR/XR/MR as well as holographic communication, will be eased with 6G since intelligence, as the key component of immersive technologies, is connected.

6G, by i) offering significantly higher bandwidth and lower latency compared to 5G, ii) integrating sensing and communication, allowing for simultaneous data collection, large volumes of processed data transmission, and continuous and timely bidirectional updates iii) being integrated with AI, enabling real-time data processing and decision-making, iv) improving the efficacy of responsiveness of the digital twin, v) supporting larger numbers of immersive devices (e.g. VR/AR headsets, Motion Capture Suits (MoCaps), haptics gloves, hand tracking toolkit (HTT), different types of wearable sensors (WSs)) to interact with DTs, and vi) enabling remote monitoring and control of remote entities with human-in-the-loop (HITL) systems, have the potential to significantly impact the development of high-fidelity immersive digital twins.

Will 6G, equipped with AI, enable real and cyber worlds to coexist simultaneously in the same synchronised space-time? This presentation analyses the potential contributions of 6G technologies in transforming various industries with a wide range of new applications through the development of highly immersive DTs as well as the challenges such as security and privacy, and the increasing complexity.

Index Terms— 6G, 5G, digital twins, metaverse, smart city, artificial Intelligence, cybernetics, immersive devices.

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