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Distributed network and service architecture for future digital healthcare

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Introduction: According to WHO, the worldwide prevalence of chronic diseases increases fast and new threats, such as Covid-19 pandemic, continue to emerge, while the aging population continues decaying the benefit-dependency ratios. These challenges will cause a huge pressure on the efficacy and cost-efficiency of healthcare systems. Thanks to the emerging technologies, such as novel medical imaging and monitoring instrumentation, and Internet of Medical Things (IoMT), more accurate and versatile patient data than ever is available for medical use. To transform the technology advancements into better outcome and improved efficiency of healthcare, the seamless interoperation of these key technologies needs to be ensured. Beyond 5G communication technologies, Edge computing, Artificial Intelligence (AI) and Virtualization have a major role in this transformation. In our work, we explore the combined use of these technologies for managing the complex tasks of connecting patients, personnel, hospital systems, electronic health records and medical instrumentation into a unified framework.

Concept: We have taken the concept, we call as "edge-cloud continuum", a base approach for implementing the computational and communication architecture for future digital healthcare scenarios. It enables utilizing the most optimal - with respect to e.g. performance, reliability or efficiency - of the three architectural tiers for deploying different system components, namely *core tier* including traditional cloud data centers, *access tier* accommodating edge servers providing e.g. low latency, and *local tier* accommodating local edge machines capable of running the most lightweight edge services. This architecture and its prototype implementation are introduced in [1].

Results: We have evaluated the feasibility of the concept with a series of real-world and simulation studies. In [2], we implemented a dynamic service deployment model that enables using distributed local edge computing as a part of the edge-cloud continuum. The results demonstrated the feasibility of our approach in a Covid-19 scenario, where a patient is first remote monitored at home, who is then, due to a weakening condition, hospitalized. Along the treatment path, the patient monitoring service is seamlessly extended to a treatment service with an oxygen mask reacting to blood oxygen saturation. In [3], we studied Blockchain-based data anonymization at the edge for improved patient privacy protection. The results revealed that improved privacy protection can be achieved with tolerable cost on performance and resource-efficiency. Most recently, in [4], we studied latency-critical computing in the edge-cloud continuum, with the objective to minimize the usage of system resources, while maximizing the number of accepted latency-limited task requests. The proposed algorithm provided high acceptance rate while it resulted in allocations close to optimal. This helps ensuring the operation of latency-critical medical applications, such as remote surgery, in resource-constrained environments under high load.

Conclusions and future work: In our recent work, we have successfully demonstrated the feasibility of the edge-cloud continuum as the base approach for efficient and secure distributed healthcare service deployment. In the next phase, we are planning to dig deeper into the special requirements of various 6G-enabled healthcare use cases, related to e.g. remote care, medical imaging, and emergency response. Therefore, based on the 6G vision, the future work will have emphasis on AI and Machine Learning (ML) based solutions for enabling context-specific optimization of treatment efficacy and resource-efficiency in the edge-cloud continuum. Moreover, the integration of Distributed Ledger Technologies (DLT) with the distributed healthcare architecture is another crucial aspect to study in the future for seeking optimal solutions for trusted data management in various healthcare scenarios.

References:

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