State-of-the-art Edge-assisted Techniques for Connected Healthcare Systems
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Abstract
With the advancements in technology, traditional professional based healthcare systems are being replaced by the connected healthcare systems. Technologies such as cloud computing and IoT become increasingly popular in this regard. However, they have some limitations like long response time and high communication costs. To this end, edge computing arises to make a revolution in this scope by pushing the computation and processes closer to the end devices where data are collected. This study investigates the state-of-the-art research leveraging edge computing technology in the connected healthcare systems.

Introduction
Connected healthcare is considered as one of the crucial parts of smart cities. As a matter of fact, the need for expanding healthcare sectors, optimized usage of health utilities and its resources, reducing healthcare costs along with preserving and improving healthcare quality level lead to the rise of connected healthcare concept [1]. As the name implies, a connected healthcare system refers to a single system in which all participants are connected through the novel technologies [2]. In today's progressive world, the fast growth of computational intelligence methods and the emergence of numerous wearable devices, coincide with the development of next-generation wireless networks, have enhanced the prevalent healthcare systems into connected healthcare strategies [3]. The connected healthcare systems facilitate participants connections and data transferring with low cost [4]. Transmitting, recording, and processing an enormous number of medical records produced by various kinds of sensors and smart devices are the inevitable parts of connected healthcare systems [5]. Offering such healthcare solutions with regards to the inadequate resources in IoT devices is crucial [6]. Although cloud and IoT deliver efficient solutions, they are not effective for handling massive amount of collected sensors’ data in critical circumstances. Hence, newly emerged distributed computing methods such as edge computing and fog computing are more suitable [7, 8]. Generally, edge-assisted IoT solutions consist of multi-layered distributed architectures trying to maintain the workload balance between the layers. Figure 1 introduces a general four-layer architecture for edge computing. This architecture includes edge IoT devices layer, edge servers layer, edge cloud layer, and cloud data center layer.

With regards to the importance role of edge assisted solutions for connected healthcare systems, various research studies exist in this scope. In this study, we examine state-of-the-art approaches and classify them into two main groups, namely patient-centric solutions and process-centric solutions as shown in Figure 2 and Figure 3. We further classify these two main groups into subgroups based on their applications (Figure 2) and based on their objective (Figure 3).

Fig. 1. The four-layer architecture of edge computing

Patient-Centric Solutions
Patient-centric methods [9] focus on computing that targets the monitoring of patients. Monitoring can be done remotely, off, or clinically. In the second classification illustrated by Figure 3, patient-centric solutions [3], regarding the target of monitoring, are classified into two groups, including prediction and detection.

Process-Centric Solutions
Process-centric methods [4] consider aspects that involve enhancing the non-patient aspects related to process management in the scope of IoT-based connected healthcare systems, such as resource allocation, improving network utilization, and data protection. Process-centric methods mainly are classified into two groups, including resource management and data management.

Figure 4 illustrates the focus of proposed methods/systems, are classified into three groups, including data-aware, network-aware, and resource-aware solutions.

Findings
The state-of-the-art edge-assisted connected healthcare solutions have been investigated with regards to their application corner, their adopted algorithms, and the mentioned parameters. The inspection findings are summarized in Figures 4, 5, 6. Figure 4 illustrates the application cases observed throughout the investigation process. Figure 5 displays the classification of adopted algorithms in the current works. The real-time future and severe requirements of connected healthcare systems lead to introducing some parameters as the critical factors in this field. Figure 6 demonstrates in what extent the important parameters have been considered in the state-of-the-art solutions.

Future Trends and Conclusion
Although different research studies have been done in implementing and designing IoT-based connected healthcare systems using edge technology, there exist various challenges and open issues that are required to be recursively addressed. Figure 7 depicts the two main challenges and future trends vividly.

References

Fig. 3. Classification of Edge-assisted healthcare solutions based on their objective.

Fig. 4. Classification of Edge-assisted healthcare solutions based on their applied cases

Fig. 5. Classification of Edge-assisted healthcare solutions based on their adopted algorithms.

Fig. 6. The usage of important parameters.

Fig. 7. Future trends and challenges.