Artificial Intelligence (AI) Driven Wireless Body Area Networks: Challenges and Directions

Honggang Wang
University of Massachusetts Dartmouth
USA
hwang1@umassd.edu

Mahmoud Daneshmand
Stevens Institute of Technology
USA
mahmoud.daneshmand@stevens.edu

Hua Fang
University of Massachusetts Dartmouth
USA
hfang2@umassd.edu

***Abstract*—Significant growth of internet applications in recent years has raised a lot of challenges to networks. One of the important applications is smart and connected health (SCH), which utilizes sensing, communication networks and artificial intelligent (AI) techniques to offer healthcare services to the users. In SCH applications, Wireless Body Area Networks (WBANs) consisting of a group of Lightweight and wearable devices designed for use within the proximity of the human body, is a key infrastructure. In this short paper, we discussed the possibility of exploring AI techniques for WBANs to improve network performance and enhance health services. In addition, we present the literature review of AI driven networks for SCH, its related challenges and future directions.**

***Index Terms*—Smart and Connected Health, Wireless Body Area Networks, Artificial Intelligence**

I. Introduction

Nowadays, we are moving to the era of artificial intelligence (AI). There are more and more applications such as autonomous driving, smart home, and smart and connected health (SCH), which are enabled by the AI. Especially, SCH utilizes sensing, communication networks and AI to enable ubiquitous healthcare services. Wireless body area networks is the key component of SCH and thus its performance is critical to support stable and secure health services. However, applying the AI into network design, services and operation is still at a very early stage. Network traffic generated by these SCH applications are streamed into the network and they have different Quality of Service (QoS) requirements. To deal with these requirements, the network must become more intelligent, agile, flexible, and programmable in the future. With the advance of Artificial Intelligence (AI) technology, there is a trend of using the AI as a powerful tool to analyze the network traffic and therefore to find the better strategies to manage WBAN resources. We believe that the future WBANs should accommodate the intelligence in order to deal with the complexity and dynamics of networks.

II. Challenges and Directions

In recent years, network technologies have been evolved very quickly from 1st generation (1G) to fifth generation (5G) cellular networks. The research communities have already started to discuss about 6G networks in which more intelligence could be included. However, more and more network applications such as smart and connected health raise new challenges to networks or have new requirements for networks. On one hand, some old challenges for networks still remain. On the other hand, some new requirements were posed by emerging SCH applications. There are more and more traffic on the networks, which requires that the future networks should have some capabilities: self configuration, self-optimization, self-healing and self-protection. There are some new emerging related technologies such as increasingly adopting SDN (Software Define Networks) [1] and NFV (Network Function Vitalization) [2]. Network automation is a potential solution to deal with challenges for future networks. In addition, the network need to have the capability of realizing self-optimization. For example, the network utilization should be maximized and all the networks resource should be fully utilized. In addition, the network operation should be simplified and the network should be easy for users to operate. We believe that some of the network challenges could be potentially dealt with AI. One of research directions is AI Assisted Wireless Communication. There are several research motivations for this research. The first is to make network management more intelligent and distributed; The second is to optimize the network resource, and thus doing better wireless resource allocation; Finally, the network environments could have significant impact on the network performance. The in-depth knowledge of environments could help us improve the network performance. Therefore, the AI assisted wireless requires several functions: network management, resource optimization and In-depth knowledge discovery in context environments.

III. AI-Driven Wireless Body Area Networks

Wireless Body Area Networks consists of a group of devices designed for use within the proximity of the human body. These devices are lightweight, wearable, with low power requirements, and also with the wireless communication capability such as using BLE, and ZigBee. The devices of WBANs may include multiple wearable sensors such as thermistor sensors, SPO2 and glucose sensors. There are several challenges from body area networks: complexity radio propagation in body area; limited resource and low power requirements; the impact of context environments on body area networks. In our studies, we observed the relationships among channel and topology dynamics and body activities as reported in [3]. It

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is clear that the channel variation is large when the body activity becomes more intensive. Body area networks has a multi-tier network structure. But why the AI is needed in this application? This is because of our observation that the network performance is significantly impacted by the human body activities. We found that the variation of RSSIs (radio signal strength indicator) is dynamically changed when the person is walking, running and jogging. This information could be very useful for us to configure the networks and optimization, which also motivates the research on machine learning based WBANs by collecting the information of human body and learning to optimize the network performance. There are other applications of AI for wireless body area networks. For example, The AI methods can be used for node localization, sensor fusion, routing and clustering, scheduling, security, QoS and dynamic spectrum access. We disucssed them one by one below. (1) Node Localization: In WBAN, location information of the node is important to detect and record the place of events, or to route packets toward desired location. Genetic Algorithm (GA) and Swarm Intelligence (SI) based AI techniques are useful for node localization. (2) Sensor Fusion: Sensor fusion is the process of aggregating the data fetched from multiple sensor nodes. This aggregation process may take place at hub, server, or cloud based on the type of the network structure. Several sensor fusion schemes based on GA, Fuzzy logic (FL), Re-enforcement Learning (RL), and Artificial Neural Networks (ANN) AI techniques have been used for wireless sensor networks (WSN) [4]. (3) Routing and Clustering: Routing is the process of determining a connected path between desired source to destination node for delivering message. Generally, at the first layer, the sensor nodes form a star topology with the center hub thus hub to node connection is single hop. However, the routing table requires more memory as the number of sensor node increases. At the second layer, a server can be connected with a number of WBANs thus the server to node connection is 2-hop. At the third layer, multiple server connects to the cloud server. Moreover, a WBAN may move from one server to another and thus the involvement of mobility makes the routing more complicated and computationally expensive in terms of computation speed and memory size. A few AI based algorithms for wireless sensor networks (WSNs) have been discussed in [5] [6]. The AI based routing algorithms are mainly based on EA (Evolutionary Algorithm), RL, SI, ANN, and Fuzzy logic. (4): Scheduling: In order to acquire and transmit data, the sensor node switches between active and sleep mode periodically to save energy. Scheduling algorithms [7] schedule active and sleep time of the sensor nodes in order to trade off between service quality and sensor battery lifetime. Also, at the cloud server end scheduling mechanism can be more intriguing considering the WBANs service. (5) Dynamic Spectrum Access: In the CR based WBAN, the hub acts as the cognition engine (CE). It performs spectrum sensing and share the resource with coexisting networks. The CE gathers information regarding the operating environment, capability, and characteristics of the radio. Then makes decision, changes the operation parameters of the radio based on the collected information and learns the impact of these actions on the performance of the radio. Some ANN based techniques have developed in spectrum sensing and dynamic spectrum access [4] [8]. Few AI techniques including artificial neural networks (ANNs), metaheuristic algorithms, hidden Markov models (HMMs), rule-based systems, ontology-based systems (OBSs), and case-based systems (CBSs) can be used to in CE implementation . However, based on the network architecture, the cognition decision and learning can be done either on hub or the server.

IV. Conclusion

In this short paper, we briefly reviewed the literature related to AI driven WBANs for smart and connected health and discussed some research challenges and potential research directions. However, the development of AI driven networks for health have still a long way to go. The related challenges not only are from the AI and its applications themselves, but also from the future network architecture design. In addition, more advanced learning algorithm will be further used to analyze the data stream from WBANs and thus could guide the network design and deployment more efficiently in the future. The development of AI driven WBANs for healthcare applications will be also fostered by the future 5G/6G networks. We believe that 6G network will accommodate more advanced AI techniques in the network management and resource allocations, thus optimizing the network performance to enable more and more healthcare applications.

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