A Distributed Federated Transfer Learning Framework for Edge Optical Network

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Abstract: This paper proposes a cross-scene, cross-spectrum, and cross-service edge optical network architecture, and designs a distributed federated transfer learning (FTL) framework to provide solutions for the intelligent edge optical network.
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1. Introduction

According to Gartner's forecast, more than 50 billion terminals and devices will be connected to the Internet in 2020. By 2025, more than 70 percent of data will need to be analyzed, processed and stored at the edge of the network [1]. In addition, during the anti-epidemic period, services such as online meetings and online teaching have surged, resulting in a surge in Internet traffic [2]. Statistics from the Ministry of Industry and Information Technology of the People's Republic of China show that Internet traffic in China during the epidemic increased by 50 percent compared with the end of last year. The above factors are the main driving forces for the development of optical networks to the edge. We need to rethink the bandwidth, cost, and network latency challenges at the edge of the optical network.

Artificial intelligence (AI) technology performs operations similar to learning and decision-making by imitating biological processes, and recently has been widely used in optical networks [3-5]. Authors in [6] stated that next generation edge optical networks can meet the requirements on higher capacity and lower latency, and presented AI-based control systems with SDN technology. Deploying artificial intelligence to remote clouds and edge clouds is an effective way to realize intelligent services [7]. Specifically, M. S. Rahman *et al.* proposed a privacy-preserving framework based on AI integrating MapReduce model for the edge networks [8]. However, taking into account the diversity of application scenarios, the complexity of service provisioning, and the uncertainty of spectrum status on the edge optical network side, an efficient and secure AI framework is urgently needed to solve these problems.

Therefore, this paper considers the application requirements of cross-scene, cross-spectrum, and cross-service in edge optical networks, and proposes a novel edge optical network architecture named 3-CS. At the same time, considering the user privacy data protection problem under the network architecture, in order to realize its efficient bearing, a distributed AI framework based on federated transfer learning is designed, which provides a solution for improving the intelligence degree of the edge optical network.

2. Network architecture and problem statement

With the rapid development of the Internet and the Internet of Things (IoT), smart terminals and IoT device terminal applications continue to increase, and device traffic has higher requirements in terms of bandwidth and delay[9][10]. For example, virtual reality (VR) and augmented reality (AR) require ultra-high bandwidth transmission. Services such as live video broadcasting require extremely low delay guarantees, while scenarios such as the Internet of Vehicles require large-scale connection guarantees[11]. The above scenario promotes the generation and application of edge computing technology which deploys a small data center on the edge of the network. Devices on the edge do not need to transmit data through the core network to the cloud data center for processing, reducing the bandwidth occupation of the core network. At the same time, it satisfies the low latency requirements of the services. Therefore, the above-mentioned demands and the emergence of new technologies simultaneously drive the development of optical networks to the edge.

The edge cross-layer and cross-domain optical network architecture is shown in Fig. 1. Due to emerging services, new application scenarios, and the expansion of the spectrum range, a cross-service, cross-scenario, and cross-spectrum (3-CS) architecture has emerged at the edge of optical networks. It is crucial that how to combine high-efficiency artificial intelligence technology to promote the more intelligent development of edge optical networks and improve its carrying capacity. Emerging services include IoT services, VR services, telemedicine services, etc. The characteristics of these services are quite different, and ordinary AI algorithm framework cannot provide rapid response across service areas. At the same time, new application scenarios continue to increase, including industrial Internet, smart healthcare, smart cities, etc. Different application scenarios have huge differences and lack the ability to interconnect. If you train different AI models for application scenarios, it will lead to a huge waste of limited edge resources, such as computing and storage. Therefore, it is urgent to design an AI architecture with strong generalization ability and safety. In addition, a full-spectrum application mode will also appear on the edge of the optical network, and cross-spectrum identification and management are also extremely challenging.

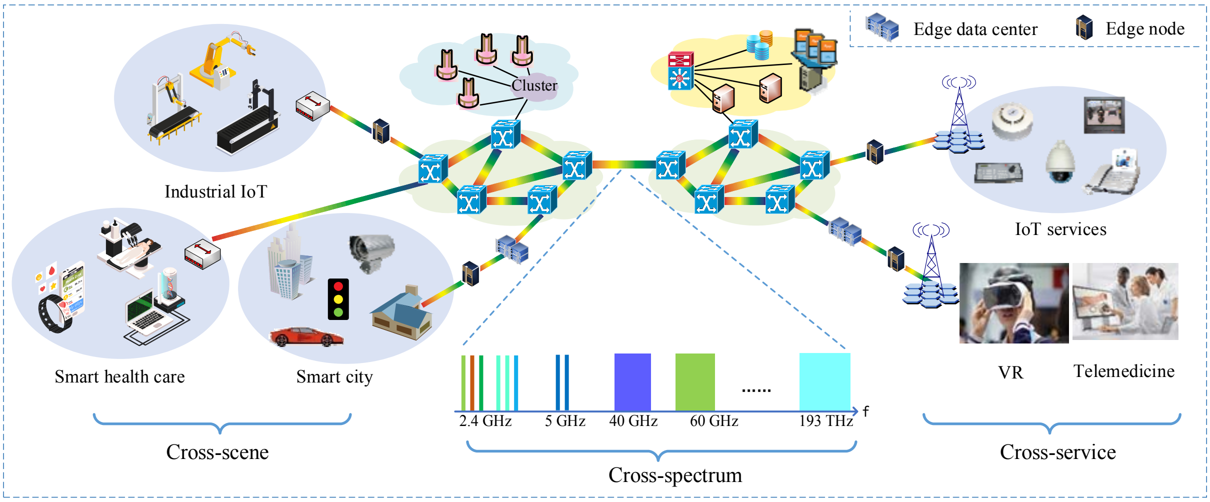

Fig.1 Edge 3-CS optical network architecture

3. The proposed FTL framework

With the interweaving of various services, scenarios, and heterogeneous resources, network operation efficiency is extremely challenging. How to improve the edge bearing capacity of the optical network is a key issue. In recent years, AI technology has achieved rapid development, which provides a broad solution for the intelligent edge of the optical network, which is conducive to the realization of the goal of its efficient bearing. It is worth noting that at the edge of the optical network, due to the diversification of application scenarios, service types and transmission resources, people's attention to security issues has also continued to increase. How to realize the training process of the AI joint model under the premise of ensuring the safe use of various data to improve the experience of all aspects of the network is very important.

This paper provides a federated transfer learning framework as shown in Fig. 2. The framework uses the sample encryption training feature of federated learning to combine with the model reuse idea of transfer learning to realize efficient model training and application under the premise of ensuring the security of user privacy data. The proposed framework contains three layers, namely the data layer, the local learning (LL) layer, and the federated transfer learning (FTL) layer. The data layer generates and stores data from different data owners. Note that these data may contain small data with great mining value. This is also one of the key issues to be solved by the framework, that is, the value utilization of small data. In the local learning layer, each data owner will use various types of local data in the data layer to carry different AI algorithms to train and generate models for different training tasks. The model parameters are encrypted and transmitted to the FTL layer to perform federated transfer learning tasks. Note that only when the FTL layer has transfer learning requirements, a query request will be initiated to the LL layer. If there is a training model for related tasks in the LL layer, the transmission action after parameter encryption will be executed.

The following simple example illustrates the whole process. Assuming that the data owner DO *3* has small data training needs, it will first find out whether there is a model for related tasks locally. If it exists, transfer learning is directly performed locally. Otherwise, the training requirements are transmitted to the FTL layer. We suppose that at the FTL layer, through matching with the database, a usable model is found. Then the federated transfer learning process is performed at this layer. Finally, a model suitable for DO *3* small data training requirements is obtained, and it is encrypted and transmitted to DO *3*. If no applicable model is found in the FTL layer, the training requirements are recorded in this layer, and query requests are sent to the LL layer periodically until a usable model is found.

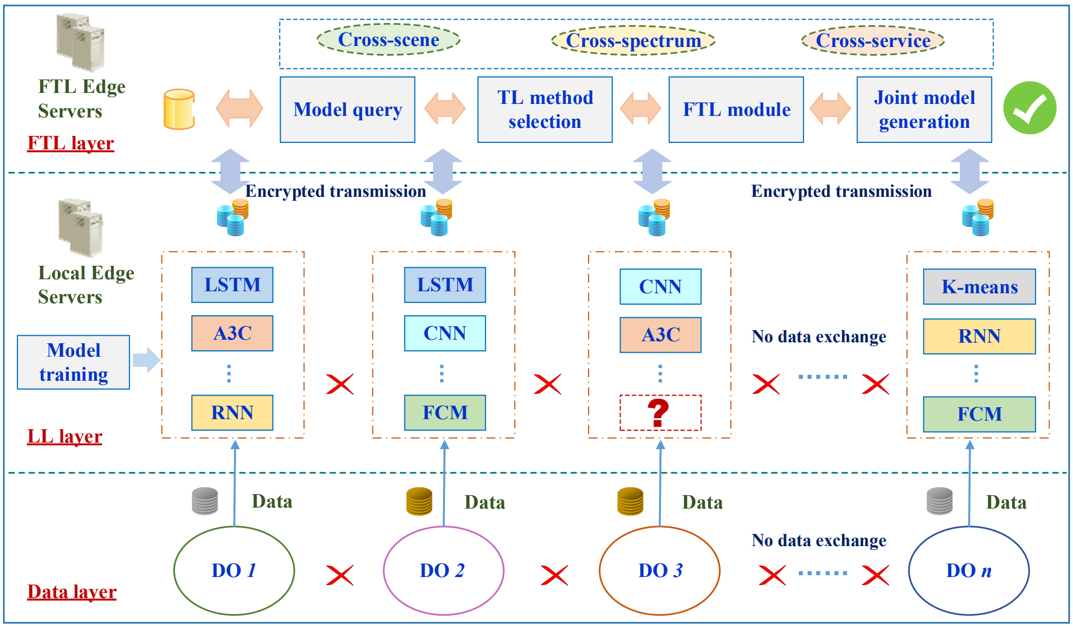

Fig.2 The proposed FTL framework

4. Conclusion

This paper first analyzes the needs of the development for the edge optical network, and proposes a cross-layer and cross-domain optical network architecture at the edge optical network. On this basis, in order to improve the intelligence of edge optical networks while ensuring data security, a federal transfer learning framework is designed. The proposed framework not only improves the carrying efficiency of the edge optical network, but also can fully mine the value of small data while protecting user data privacy, and also provide users with more efficient and effective services.

5. Acknowledgments

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