Application of Machine Learning in Space–Air–Ground Integrated Network Data Link

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Abstract. The space–air–ground integrated network is an emerging network architecture integrated by satellite, aerial network, and ground communication, which can provide seamless connection on a global scale. However, the limited energy and spectrum resources cannot meet the growing communication needs, and its high heterogeneity, complex variability affect the reliable and efficient end-to-end transmission of services. In addition, machine learning is widely used. Using machine learning algorithms to solve problems in the space–air–ground integrated network is a new research idea for us. Therefore, this paper first introduces the concept and characteristics of apace–air–ground integrated network, summarizes, and analyzes the application of machine learning algorithms in solving the problems of resource allocation, attack detection, target recognition and location and security authentication of the space–air–ground integrated network, and looks forward to its prospects for development in space–air–ground integrated network.

Keywords: Space–air–ground integrated network · Machine learning · Attack detection · Resource allocation · Security authentication · Target recognition · Location

1 Introduction

Based on the existing communication network technology, the space–air–ground integrated network connects multiple networks into a huge distributed heterogeneous network, which can realize the global sharing of information resources and can be used in many practical fields, such as observations, intelligent transportation systems, military missions, and disaster relief [1]. The space–air–ground integrated network includes three layers: space-based network, air-based network, and ground-based network. The network architecture is shown in Fig. 1. The three layers can work independently or be interconnected and have good global and regional coverage capabilities [2].

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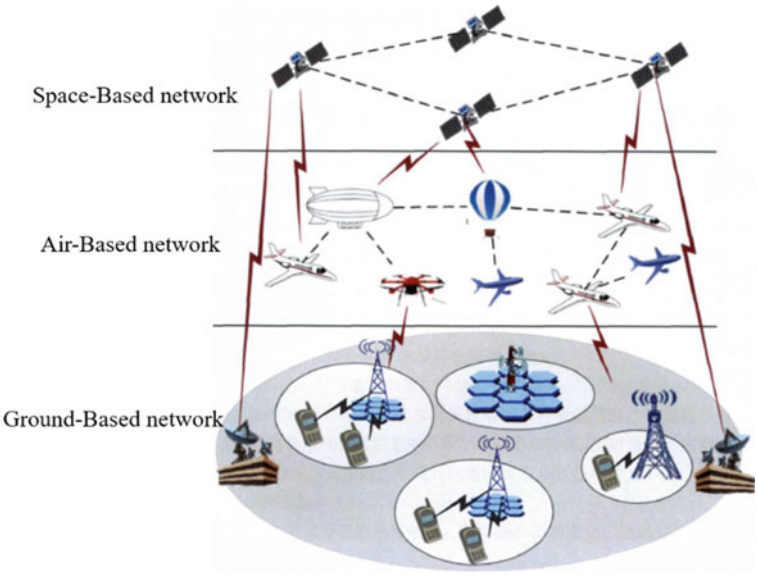

Fig. 1 Architecture of space–air–ground integrated network

The space–air–ground integrated network is a huge, nonlinear, dynamic, and complex system. There are many types of services in the network, and the network environment is dynamic and changeable [3]. The network lacks adaptive capabilities and cannot adaptively respond to changes in the network environment. The dynamic and uncertain nature of the network makes it increasingly difficult to manage and control it [4]. With the development of machine learning technology, researchers are paying more and more attention to the intersection of wireless network and artificial intelligence technology. Using machine learning technology to solve the problem of space–air–ground integrated network has become a research hotspot [5, 6].

This paper analyzes and summarizes the application of the machine learning algorithm in solving the space–air–ground integrated network problems and looks forward to its development prospects in the space–air–ground integrated network.

2 Background and Related Work

2.1 Machine Learning

Machine learning can be divided into three categories: supervised learning, unsupervised learning, semi-supervised learning, and reinforcement learning.

Supervised Learning: In supervised learning, the input data is called "training data," and each set of training data has a clear identification or result. When building a prediction model, supervised learning continuously adjusts the prediction model by comparing the prediction result with the actual result of the "training data" until the prediction result of the model reaches an expected accuracy rate.

Unsupervised learning: In unsupervised learning, the data is not specifically identified, and the learning model is to infer some internal structure of the data.

Semi-supervised learning: In this learning mode, part of the input data is marked, and the other part is not marked. This learning model can be used for prediction, but the model first needs to learn the internal structure of the data in order to reasonably organize the data for prediction.

Reinforcement learning: In reinforcement learning, the input data is directly fed back to the model, and the model must make adjustments to this immediately. Unlike supervised learning, the input data is only used as a way to check whether the model is right or wrong.

2.2 Problems of the Space–Air–Ground Integrated Network

The main challenges of the space–air–ground integrated network are:

Limited Resources: Limited spectrum resources and bandwidth resources have always been issues that need to be discussed in the field of wireless communications. Compared with ground networks, the environment and technology limitations of satellites and air platforms have limited load capacity and are more susceptible to resource constraints [7].

Security Authentication: The space–air–ground integrated network integrates a variety of networks, and illegal users can access them through various means, so the identity of the user needs to be authenticated [8].

Attack Detection: Because satellites and aerial platforms are far away from ground terminals, their high exposure is susceptible to various types of network attacks. Therefore, effective security measures must be adopted to ensure the normal operation of the space–air–ground integrated network [9, 10].

Target Recognition and Location: Due to the high mobility of satellites and air vehicles, the network topology is constantly changing, and the recognition and location of node targets in the network are also an urgent problem to be solved [11, 12].

3 Applications Survey

There are four main problems in the space–air–ground integrated network: limited resources, target recognition and location, attack detection, and security authentication. There are many kinds of machine learning algorithms. In this section, we will introduce in detail the application of machine learning algorithms in the space–air–ground integrated network.

3.1 Limited Resources

The load capacity of space–air–ground integrated network is limited, so it is more susceptible to resource constraints. Network traffic needs to be optimized, which involves

issues such as traffic distribution, link scheduling, and energy control, and its complexity increases exponentially with network size. In order to solve this kind of large-scale optimization problem, traditional methods usually use heuristic algorithms or iterative algorithms to solve the problems. These algorithms usually only get suboptimal solutions, or the algorithm requires a long convergence time. In real time, this will cause transmission delay or performance degradation. Unlike most traditional iterative search methods for optimal solutions, the current common method is to use machine learning algorithms to design resource allocation models.

3.2 Security Authentication

Since the space–air–ground integrated network is integrated by different networks, we can collect user access features of each network, then use machine learning algorithms to train the collected feature vectors, and finally use the trained model to authenticate the identity of the new user.

3.3 Attack Detection

Due to the large scale of the space–air–ground integrated network, network attacks mainly come from two aspects: one is the existence of malicious transmission nodes inside space–air–ground integrated network; the other is the external network intrusion.

Malicious Nodes Detection: The detection method of malicious nodes can usually take the behavior feature vectors of the same type of nodes in the space–air–ground integrated network as the input set, and then use machine learning algorithms to classify the behavior of the nodes.

Network Intrusion Detection: According to the implementation details of network intrusion, intrusion detection systems can be divided into feature-based intrusion detection technology and anomaly-based feature detection technology. Feature-based intrusion detection technology uses a set of predefined malicious behavior patterns and attack characteristics for intrusion detection, while anomaly-based intrusion detection systems use behaviors other than normal as features to detect intrusion behaviors.

3.4 Target Recognition and Location

Due to the mobility of satellites and air networks, multiple targets need to be identified and located. Because of the large number of objects and high speed, the recognition rate and positioning accuracy of traditional recognition and positioning technologies are not accurate. Using machine learning algorithms to recognize multiple targets can reduce the error of traditional recognition algorithms and improve the accuracy of target recognition. Commonly used target recognition algorithms are faster-RCNN, YOLO, SSD, and so on.

4 Conclusion

This paper takes the space–air–ground integrated network as the background, introduces its detailed structure, discusses the problems of the space–air–ground integrated network

from four angles, and introduces the application of machine learning in the space–air–ground integrated network. It provides new ideas for studying and solving the problem of the space–air–ground integrated network.

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