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Communication-sensing Integrated Architecture and Key Technologies for 6G

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Abstract

With the rapid development of 5G communication technology, people's research and exploration of 6G communication have begun. The goal of 6G communication is to achieve higher data rates, lower latency, and wider connectivity ability, which will further promote the development and application of communication technology. However, with the rapid development of wireless communication, existing spectrum resources have become strained, requiring finding new spectrum resources to support higher data rates and more connected devices. To meet these requirements, the communication-sensing integrated architecture becomes one of the key technologies, and it also becomes a complex problem. This paper aims to introduce the research progress of communication and sensing integration architecture and key technologies for 6G, including sensing networks, data fusion, intelligent decision-making, and so on, and to look forward to the future development direction. These studies and explorations will also provide support and help for the development of 6G communication to a certain extent, and promote the further development of communication technology.

Keywords

6G communication; communication perception integration; perception network; data fusion; intelligent decision-making

With the rapid development of technologies such as the Internet of Things, artificial intelligence, and big data, people's demands and expectations for the next generation of communication technology 6G are increasing. 6G communication aims to provide higher data rates, lower latency, and wider connectivity to meet the needs of future smart transportation, smart cities, telemedicine, and other application scenarios. To achieve these goals, a communication-aware integrated architecture is considered as one of the key technologies. The integrated architecture of communication perception integrates functions such as perception, data fusion, and intelligent decision-making to achieve global optimization and intelligent decision-making, thus improving network performance and user experience.

1. An overview of the integrated architecture

1.1 Features and challenges of 16 G communication

With the commercialization of 5G communication, people's research and exploration of 6G communication has begun.6G communication is characterized by a higher data rate, lower latency, and wider connectivity capabilities. However, achieving these goals addresses many challenges. 6G communication will involve a variety of network technologies and equipment, such as cellular networks, satellite communication, the Internet of Things, etc. How to achieve the seamless connection and collaborative work between these heterogeneous networks is a complex problem. With the accelerated development of digitalization, a large number of devices need to be connected to the 6G network.

How to effectively manage and schedule these devices to ensure the reliability and performance of the network is a key problem. At the same time, energy consumption becomes an important issue [1].

6G communication needs to explore new energy management strategies and technologies to reduce the energy consumption of communication equipment and achieve more sustainable communication networks. To address these challenges, a communication-aware integrated architecture has been proposed and attracted much attention. This architecture integrates functions such as perception, data fusion, and intelligent decision-making, obtains information about environment and network status through the network perception, integrates and analyzes data from different sources by using data fusion technology, and finally realizes optimal allocation of resources and adaptive network management of networks through intelligent decision-making. The application of communication perception integration will help to improve the intelligence and adaptability of the network to meet the requirements of 6G communication.

1.2 Concept and significance of communication perception integration

Communication and perception integration refers to the integration of functions such as perception, data fusion, and intelligent decision-making together to form a whole architecture. Under this architecture, the sensing network obtains information about the environment and network status through sensors and other devices. Data fusion technology integrates and analyzes data from different sources, and intelligent decision-making uses this information to optimize the allocation of resources and network management. The significance of the integration of communication perception is to improve the intelligence and adaptability of the network so that the network can better adapt to the complex and dynamic environmental changes, and provide better user experience and service quality. The environmental information obtained through the perceptual network can help the network to perceive and understand different scenarios and needs, thus in more accurate decision-making and resource allocation. Data fusion technology can integrate and analyze data from different sources, extract more comprehensive and accurate information, and provide a more reliable basis for network decision-making. Intelligent decision-making can automatically manage and schedule the network according to the results of perception and data fusion, and optimize the utilization of resources and network performance.

Communication perception integration has a wide range of application fields, including wireless communication networks, the Internet of Things, intelligent transportation, smart cities, etc. In the wireless communication network, communication perception integration can help the network to better adapt to different communication environments and user needs, and provide a higher data rate and more reliable connection. In the Internet of Things, the integration of communication perception can realize the intelligent perception and management of the Internet of Things devices and the environment, and improve the efficiency and reliability of the Internet of Things. In the field of intelligent transportation and smart cities, the integration of communication and perception can obtain information of traffic and urban environment through perception and integration, and realize the optimal allocation of intelligent traffic management and urban resources [2].

1.3 Basic components of the integrated architecture

The integrated architecture of communication perception integrates the three basic components of perception network, data fusion, and intelligent decision-making together, realizing the perception of the environment and network state, the integrated analysis of data, and the optimal configuration and network management of intelligent decision-making. Each component plays an important role in the integrated architecture, working together to improve the intelligence and adaptability of the network. The perceptual network is the foundation of the integrated architecture of communication perception, which is responsible for acquiring information about the environment and network status. It includes a variety of sensors, detectors, and monitoring equipment, using sensing technology to collect and transmit data in real time. These sensing devices can include temperature sensors, humidity sensors, light sensors, wireless signal detectors, etc., which are used to obtain environmental parameters, network topology, signal quality, and other information. The data fusion module is a key component of the communication-sensing integration architecture for integrating and analyzing data from different sources. It uses data processing and algorithm technology to process, fuse, and analyze various data acquired by the perceptual network and extract useful information. Data fusion can be either sensor-level data fusion or network-level data fusion. It can be obtained through the integration of multi-source data, a more accurate and comprehensive environment, and network status information. The intelligent decision module is the decision engine of communication perception integration architecture. According to the results of perception and data fusion, optimization algorithms and decision strategies are adopted for resource allocation and network management. The intelligent decision module can make intelligent decisions according to the current network state, user needs, environmental changes, and other factors, such as spectrum allocation, power control, routing, etc., to optimize the network performance and resource utilization efficiency.

2. Design and optimization of the perceptual network

2.1 Basic principles and functions of the perceptual network

The perception network is the core component of the integrated architecture of communication perception. Its basic principle is to use sensor technology and algorithm to perceive the state of the network and environment in real time. The functions of perception networks include environment perception, spectrum perception, and topological perception, and the information obtained through perception technology can be used for the management and optimization of network resources. The rationale for a sensing network is to collect data on the environment and network status through sensors deployed in the network. These sensors can be various types of devices, such as wireless sensor networks, vision sensors, sound sensors, etc. These sensors can be distributed in various locations to form a distributed sensing network. The sensing network collects the data in real time through the sensing technology and transmits the data to the data fusion and intelligent decision-making module for further processing and analysis.

The functions of the perception network mainly include environmental perception, spectrum perception, and topological perception. Environmental sensing collects various parameters and indicators in the environment through sensors, such as temperature, humidity, air pressure, etc., as well as objects and personnel in the environment [3]. Spectrum perception refers to the monitoring and analysis of the use of wireless spectrum through perception technology, including frequency, bandwidth, and signal intensity. Topological perception refers to the perception of the network topology and connection relationship by the perceptual network, including information such as node location, connection state, and link quality. The data of the perceptual network can be used for the management and optimization of the network resources. The environment and network state information obtained by sensing the network can help the network to allocate and schedule resources, and improve the capacity and efficiency of the network. For example, the power and transmission rate of the network can be dynamically adjusted according to the environmental sensing data to accommodate different environmental conditions. Spectrum-aware data can be used for spectrum management and dynamic spectrum allocation to improve spectrum utilization. Topology-aware data can be used for routing optimization and link quality monitoring to improve the reliability and performance of networks. The sensing network senses the state of the environment and network in real time through sensor technology and algorithm, providing key data support for the integrated architecture. The functions of the perception network include environment perception, spectrum perception, and topological perception, through which the management and optimization of network resources can be realized, and the network efficiency and performance can be improved.

2.2 Sensor technology and algorithms in the perception network

Sensor technologies and algorithms in sensing networks are the key to realizing sensing function. Sensor technologies include wireless sensor networks, optical sensors, acoustic sensors, etc., which can collect and transmit data of the environment and network status in real time. The selection and deployment of sensor technology need to consider the sensor energy consumption, communication distance, sampling rate, and other factors. In addition, the perception network also needs to use various algorithms to process and analyze the sensor data, such as signal processing algorithm, machine learning algorithm, data fusion algorithm, etc. Wireless sensor network is one of the commonly used sensor technologies in sensing networks. It consists of a large number of wireless sensor nodes, which can be self-organized to form a distributed sensing network. These nodes can collect the data on the environment and network status in real time, and transfer the data to the data fusion and intelligent decision-making module for processing. The advantages of wireless sensor networks are flexibility and scalability, which can be deployed and adjusted to demand.

Optical sensors also have an important role in sensing networks. Optical sensor uses the optical principle for data acquisition, which can realize high-precision image and video data acquisition. In sensing networks, optical sensors can be used for tasks such as environmental sensing, object detection, and tracking. By acquiring image and video data of the environment, more detailed environmental information can be obtained, such as the position, shape and motion state of objects. The algorithms of optical sensor include image processing algorithm, target recognition algorithm and motion tracking algorithm.

Acoustic sensors are another commonly used sensor technology in sensing networks. Acoustic sensors can sense sound and acoustic signals in the environment and convert them into digital data for analysis and processing. In perceptual networks, acoustic sensors can be used for tasks such as sound source localization, sound recognition, and environmental monitoring. By analyzing sound data, information about sound characteristics, sound source locations, and sound events in the environment can be obtained. The algorithms of acoustic sensors include an audio processing algorithm, sound source location algorithm, and sound recognition algorithm. In addition to sensor technology, sensing networks also need to use various algorithms to process and analyze sensor data. The signal processing algorithms can filter noise reduction and feature extraction of sensor data to improve data quality and accuracy. Machine learning algorithms can use perceptual data for tasks such as pattern recognition, classification, and prediction, so as to realize intelligent perception and decision-making [4]. Data fusion algorithms can integrate data from different sensors to improve the reliability and accuracy of perceptual results.

2.3 Data processing and information fusion of the perceptual network

In perceptual networks, it is necessary to process and fuse the data collected by a large number of sensor nodes to extract useful information and support network decision-making and applications. Data processing and information fusion are important links in the perception network, involving technologies and algorithms in signal processing, data mining, pattern recognition, and other fields. Data processing mainly includes data preprocessing, feature extraction, data compression, and encoding. Firstly, the raw data is denoised, filtered, and corrected to improve quality and accuracy. Then, representative features are extracted from the raw data through the feature extraction algorithm for subsequent analysis and decision-making. Data compression and encoding technology can effectively reduce the data storage and transmission overhead, improve the network efficiency and performance. Information fusion is the result of the integration and fusion of data and information from different sensor nodes to generate a more comprehensive and accurate description of the target or environmental state. Information fusion can be divided into low-level sensor-level fusion and high-level data level, feature level, and decision-level fusion. Sensor-level fusion is mainly used to integrate and correct the raw data collected by the sensor nodes to eliminate redundancy and contradictory information. Data level, feature level and decision level fusion is the integration and coordination of data, characteristics and decisions of different sensor nodes to obtain more accurate and reliable global information.

2.4 Energy management and optimization of the perception network

The sensor nodes in the sensing network are usually powered by batteries, and energy is an important factor limiting their running time and performance. Therefore, energy management and optimization are one of the core problems in perceptual network design. Effective energy management can extend the life of the network, improve the energy efficiency of the nodes, and support the sustainable operation of perceptual tasks. Energy management involves node power consumption control, energy collection and conversion, energy distribution, and energy conservation. First, the power consumption control technology is used to reduce the energy consumption of nodes, such as using low-power sensors and optimizing communication protocols, and sleep mechanisms. Second, the energy collection and conversion technology can utilize the energy sources in the environment, such as solar energy, vibratory energy, and thermal energy, to charge or power the nodes. Then, the limited energy resources are allocated to different nodes to meet the demands of the perceptual task. Finally, the energy-saving technology can reduce the energy consumption of nodes and extend the life of the network through data compression, task scheduling, and energy perception. Energy optimization is to maximize the energy utilization efficiency and performance of the perceptual network by optimizing algorithms and strategies on the premise of ensuring the perceptual task requirements [5]. For example, by optimizing the deployment and coverage of sensor nodes, reducing redundant and repetitive perceptual data, and reducing energy consumption.

In addition, through intelligent scheduling and routing algorithm, the data transmission path and the working state of the nodes are optimized to reduce energy consumption. Energy optimization can also combine the characteristics of perceptual tasks and the actual situation of the network, and develop reasonable energy management strategies to realize the optimal use of energy. Through effective data processing and information fusion, energy management and optimization, the perceptual network can achieve accurate perception of the environment and goals, and provide reliable decision support. The application of these key technologies and algorithms will promote the development and application of perceptual networks in various fields, and bring more convenience and benefits to people's lives and work.

3. Conclusion

This paper first introduces the characteristics and challenges of 6G communication, pointing out the importance of communication perception integration as a key technology. Then we outline the concept and significance of communication perception integration and emphasize its role in improving network intelligence and adaptability. In the basic component of the integrated architecture of communication and perception, the perception network is the core, and the perception of the environment and the network state is realized through the sensor technology and the algorithm. Finally, we explore the design and optimization of perceptual networks, including the choice of sensor technology and algorithms, as well as their optimization methods and strategies. These studies and explorations will provide guidance and support for the development of 6G communications and promote the innovation and application of communication technology.

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