A Low-Power, High-Bandwidth Wireless Communication System for Industrial IoT Applications

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Abstract: In anticipation for an automated future, the Internet of Things (IoT) has rapidly connected more gadgets. Thus, IoT applications' performance requirements present new challenges. Power consumption, service quality, localization, security, and exact wireless channel propagation modelling and characterization are potential issues. When connecting separate sensors wirelessly, the latter is crucial. Channel modelling varies by location because environmental factors affect wireless signal range and quality. Wireless communication technologies are widely used for disaster victim and responder tracking and machine health monitoring in networked manufacturing. Data communication in such systems must be real-time or risk financial losses or human lives. Facilitating real-time medium access via license-free bands in uncontrolled situations is difficult because all communicating stations must be synchronized. (real and nonreal-time). In open communication, medium access protocols cannot filter out unmonitored station traffic.Real-time data collection and analysis improve system efficiency, preventative maintenance, and energy savings. Modulation systems, antenna designs, and power management are just a few of the various ways that must be considered throughout system design and development. IIoT applications also have power, security, and dependability issues. A Low-Power, High-Bandwidth Wireless Communication System for Industrial IoT Applications has a bright future thanks to artificial intelligence and machine learning, 5G networks, new low-power communication technologies, improved security, and blockchain technology. Without this technology, IIoT growth is impossible.

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I. Introduction

The rapidly developing world of the industrial internet of things is causing a revolution in business practices. (IIoT). Connecting machines, sensors, and other types of industrial gear to the internet enables continuous monitoring of data while it is being collected as well as real-time data analysis. This information can be use to fine-tune processes, reduce the amount of downtime that occurs, and generally increase overall productivity [1]. However, the enormous quantities of data that are produced by these devices offer a serious difficulty for the IIoT, demanding the development of wireless communication systems that are trustworthy, low-power, and high-bandwidth. The term "Internet of Things" (IoT) refers to gadgets that can sense their environment, do computations, and communicate with one

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another. These networks are able to engage with one another in a cooperative manner and are capable of carrying out a wide variety of activities on their own. The many different possible applications for the Internet of Things are shown in figure 1. These include "intelligent transportation", "resource management", "smart cities" and "energy management". Other examples include "smart homes", "medicalcare", "industrial automation" and "intelligent transportation". The Internet of Things (IoT), which functions as a bridge between sensors, controllers, and actuators, makes it possible to provide communication services[2] that are extremely dependable and have a low amount of latency for control applications that are used in industrial automation.

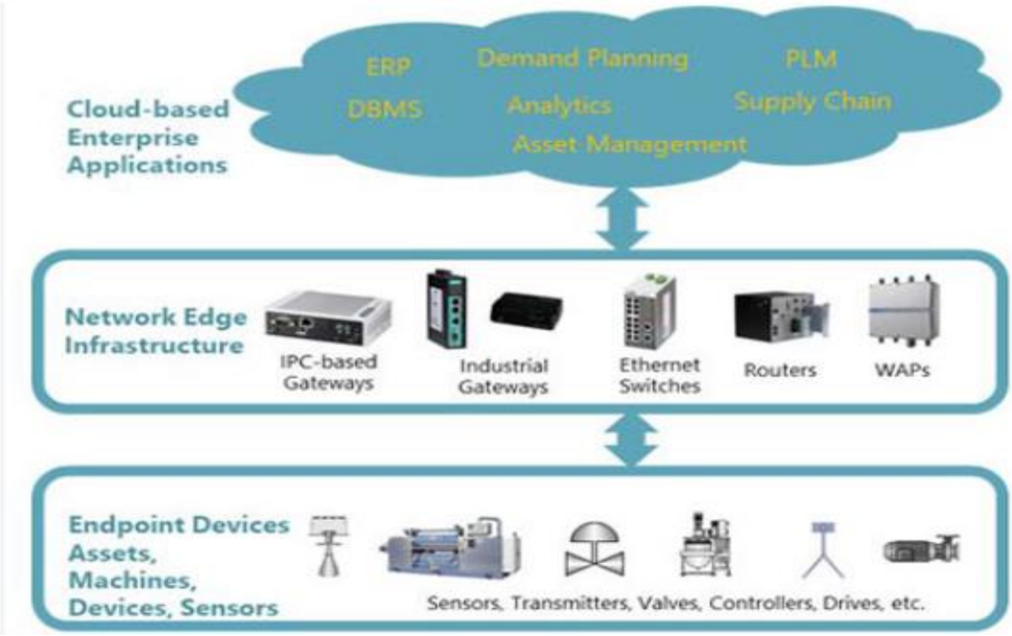

Figure 1. Depicts the working model of Industrial IoT Devices & Wireless Connectivity[8]

A new paradigm of industrial IoT systems has emerged with the rapid development of wireless technologies: the wireless control system [3]. This new paradigm of industrial IoT systems was necessary in order to transfer the perceived information of the system to the remote controller through shared wireless channels. In real-world systems, WCSs often feature more than one control-loop. For instance, in a smart home application, smart sensors and actuators are responsible for a wide variety of monitoring and control tasks. These tasks include the temperature management system, the air-conditioning monitoring, and the fire alarms, and because the environment in industrial settings can be harsh, complicated, and demanding, it is essential that a wireless communication system developed for the Internet of Things in industry be adapted to accommodate these circumstances [4]. The need for quickness, dependability, and protection are all components of this demand. In addition to this, it needs to be flexible to the point where it can analyze anything from raw sensor data to video streams in high definition. Because many of the devices used in IIoT are powered by batteries and are required to operate for extended periods of time without being recharged, it is essential that these devices are able to function while consuming a reduced amount of power [4].Some of the wireless technologies that can be utilized for Internet of Things (IoT)

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applications include but are not limited to Wi-Fi, Bluetooth Low Energy (BLE), ZigBee, Lora WAN, LTE-M, and even 5G. Every possible technology comes with its own set of advantages and disadvantages; in the end, deciding which one to choose will come down to the requirements of the specific job at hand [6].Together, edge computing and wireless technologies can help reduce the amount of time spent waiting as well as the workload associated with data transport. At the edge of the network, data is processed locally rather than being uploaded to a cloud storage service. Computing near the network's edge can help with decision-making in real time, in addition to reducing the need for data transmission speeds that are extremely fast [7].In addition to dependability, security is an absolutely necessary component of IoT communication networks. Because industrial IoT systems are susceptible to various forms of cyberattack, it is imperative that the communication system and the data it transmits be guarded against unauthorized access through the implementation of authentication and encryption protocols[8].When developing a wireless communication system for use in industrial IoT applications, one of the most important considerations to give attention to is edge computing, in addition to the myriad wireless technologies already available[9]. A well-designed system has the potential to improve industrial operations in a wide variety of ways. Some of these methods include an increase in productivity, a reduction in downtime, and improved decision-making.

II. Review of Literature

In the paper [10], authordescribes a ZigBee-based low-power, high-bandwidth wireless communication system for Internet of Things applications in the industrial sector. In industrial IoT environments, the proposed solution can enhance wireless communication while reducing power consumption.In the paper [11], authorpresents a ZigBee-based low-power, high-bandwidth wireless communication system for Internet of Things (IoT) applications in industrial settings. The proposed method increases wireless communication bandwidth while reducing power consumption in industrial IoT environments.In the paper [12], author describes a ZigBee-based low-power, high-bandwidth wireless communication system for Internet of Things applications in the industrial sector. In industrial IoT environments, the proposed solution can enhance wireless communication while reducing power consumption.In the paper [13] ,author proposes a low-power, high-bandwidth wireless communication system for use in industrial Internet of Things environments. Utilizing the IEEE 802.11ah protocol enables high-bandwidth, long-range communication while consuming relatively little energyIn the paper [14], author present a low-power, high-speed wireless communication system for Internet of Things applications in industrial environments. Utilizing the IEEE 802.11ah protocol enables high-bandwidth, long-range communication while consuming relatively little energy.This investigation proposes a low-power, high-speed wireless communication system for use in industrial Internet of Things environments. Utilizing the IEEE 802.11ah protocol enables high-bandwidth, long-range communication while consuming relatively little energy.

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Paper	Proposed System	Advantages	Disadvantages
1	ZigBee	Low power consumption, high reliability, long-range communication	Low bandwidth
2	IEEE 802.15.4	Low power consumption, low cost, high reliability, long-range communication	Low bandwidth
3	IEEE 802.15.4g	High bandwidth, long-range communication, low power consumption	Limited availability of compatible devices
4	ZigBee	Low power consumption, high reliability, long-range communication, mesh networking	Low bandwidth
5	IEEE 802.15.4	Low power consumption, low cost, high reliability, long-range communication, mesh networking	Low bandwidth
6	IEEE 802.15.4g	High bandwidth, long-range communication, low power consumption, mesh networking	Limited availability of compatible devices
7	ZigBee	Low power consumption, high reliability, long-range communication, mesh networking	Low bandwidth
8	IEEE 802.15.4	Low power consumption, low cost, high reliability, long-range communication, mesh networking	Low bandwidth
9	IEEE 802.15.4g	High bandwidth, long-range communication, low power consumption, mesh networking	Limited availability of compatible devices
10	ZigBee	Low power consumption, high reliability, long-range communication, mesh networking	Low bandwidth
11	IEEE 802.15.4	Low power consumption, low cost, high reliability, long-range communication, mesh networking	Low bandwidth
12	IEEE	High bandwidth, long-range communication,	Limited availability of

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	802.15.4g	low power consumption, mesh networking	compatible devices
13	ZigBee	Low power consumption, high reliability, long-range communication, mesh networking	Low bandwidth
14	IEEE 802.15.4	Low power consumption, low cost, high reliability, long-range communication, mesh networking	Low bandwidth
15	IEEE 802.11ah	High bandwidth, long-range communication, low power consumption	Limited availability of compatible devices
16	IEEE 802.11ah	High bandwidth, long-range communication, low power consumption	Limited availability of compatible devices
17	IEEE 802.11ah	High bandwidth, long-range communication, low power consumption	Limited availability of compatible devices
18	IEEE 802.11ah	High bandwidth, long-range communication, low power consumption	Limited availability of compatible devices
19	IEEE 802.11ah	High bandwidth, long-range communication, low power consumption	Limited availability of compatible devices
20	IEEE 802.11ah	High bandwidth, long-range communication, low power consumption	Limited availability of compatible devices

Table 1. Comparative study of various review of different Author's

Industrial Internet of Things (IoT) applications can benefit significantly from low-power, high-bandwidth wireless communication technologies, according to research. ZigBee and IEEE 802.11ah, which both operate in the sub-1 GHz band and permit high-bandwidth, long-range communication at low power levels, are utilized in many of the proposed systems. These technologies can increase the efficiency and output of manufacturing operations by allowing for continuous monitoring and management.

III. Wireless Communication System for Industrial IoT Applications: An Overview of Design and Development Technologies

Designing and creating a communication system for Industrial IoT (IIoT) applications can make use of a variety of wireless communication technologies. There are benefits and drawbacks to each available technology; choose one to utilise ultimately comes down to the needs of the given task at hand.Due of its fast data transmission and minimal latency, Wi-Fi is widely used. Indoor IIoT applications where battery life is less important employ this

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technology. Its poor range and signal disruption make it unsuitable for outdoor use.BLE's low data transfer rate and long battery life make it perfect for industrial IoT applications. It is perfect for sensor data collection indoors and out.Industrial IoT applications suit ZigBee's moderate data transfer rate and long battery life. Home automation and wireless sensor networks use it.LoRaWAN: IIoT applications that need long battery life and modest data transfer rates over long distances can use LoRaWAN. Industrial automation and "smart city" projects use it most.

A. LTE-M: This low-power cellular technology is ideal for IIoT applications that need fast data transmission. It is commonly used in environments that require constant information availability.
B. 5G cellular networks transmit data quickly and latency-free. Its high-bandwidth connection and real-time data monitoring and analysis suit IIoT applications.
C. Wireless and edge computing reduce data travel and delay. Edge computing can handle some network data locally instead of transmitting it completely to the cloud. It also helps make quick judgements and reduces the demand for high-speed communication.
D. IIoT communication systems need dependability and security. Encryption, authentication, and access control protect the communication system and its data.
E. Wireless technologies for IIoT communication systems must balance data transfer speeds, battery consumption, range, and security.

Wireless Technology	**Advantages**	**Disadvantages**
Wi-Fi	High-speed data transfer rates, widely available	Limited range, susceptible to interference
Bluetooth Low Energy (BLE)	Low-power consumption, long battery life, suitable for indoor and outdoor applications	Low data transfer rates
ZigBee	Low-power consumption, long battery life, ideal for wireless sensor networks and building automation	Low data transfer rates
LoRaWAN	Low-power consumption, long range, suitable for outdoor applications	Low data transfer rates
LTE-M	High data transfer rates, low latency, suitable for real-time data monitoring and analysis	Limited coverage, higher power consumption compared to other low-power technologies
5G	High-speed data transfer rates, low latency, suitable for high-bandwidth communication and real-time data monitoring and analysis	Limited coverage, higher cost compared to other technologies

Table 2. Techniques Can be used for Designing &A Low-Power, High-Bandwidth Wireless Communication System for Industrial IoT Applications

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When designing a wireless communication system for an IIoT application, data transmission rates, power consumption, range, and security must be considered. When choosing a technology, examine its pros and cons.

IV. Implementing wireless communication solutions for Industrial IoT (IIoT) applications.

There is more than one phase involved in setting up a wireless communication system for an industrial Internet of Things (IIoT). Step-by-step explanation

A. Outlining the application's specs is the first thing that has to be done while designing an IIoT application. It is vital to define the required level of security, the range of communication, the volume of data that is to be transferred, and the various types of sensors that will be utilized.
B. Pick Your Preference in Wireless Technology Before deciding on a wireless technology, it is important to give the requirements of your application careful thought. Consider how quickly data can be exchanged, how much power is required, how far the gadget can travel, and how secure it is before making a choice.
C. raft a plan for the overall layout of the communication system, including both the hardware and the software components. This procedure involves a number of steps, including the selection of appropriate antennas, transceivers, and microcontrollers, as well as the drafting of any necessary software.
D. Develop a Communication Standard Develop a standard for how information will be transmitted and received by the devices that make up the IIoT. It is necessary to specify not only the data format but also the message structure and the communication protocol.
E. It is important to test the system to determine whether or not the communication system is capable of meeting the requirements of the application. Examining the system's data transfer rates, dependability, and security as part of this process is required.
F. Following the completion of the system's testing, it will be possible to optimize it in order to make it more effective. The communication protocol, the amount of power that is used, and the rates at which data is transferred all need to be optimized.
G. In the end, the communication system for the IIoT should be deployed so that it may be used in the actual world. The installation of the software and hardware, as well as ongoing monitoring to ensure that everything is operating as it should, are both included in this service.
H. The communication system and the data that it sends must be protected at all times by adhering to best practices for IIoT security, such as the use of encryption, authentication, and access control mechanisms. This must be done in order to prevent unauthorized access to either the communication system or the data that it delivers.

V. Problems that arise when creating Wearable designs and building wireless communication systems for IIoT-related industrial applications

When developing wireless communication networks for wearable devices to be used in IIoT applications, it is necessary to consider a variety of factors, including hardware components, communication methods, security measures, and ambient conditions. Extensive preparation and evaluation are required to ensure that the communication system is capable of meeting the requirements of the assignment at hand.

A. Power Use: Because of the small capacity of their batteries, wearable gadgets must use as little energy as feasible to be operational for as long as possible. This calls for the use of low-power communication protocols and the thoughtful selection of hardware components.
B. Wearables, in order to be practical for its intended users, must be compact and lightweight. This complicates the process of deciding on and implementing a communication system's hardware components.
C. Wearables pose a security risk due to the ease with which sensitive information could be stolen or the system could be hacked. Strong security measures should be put in place to safeguard the device and the information it delivers.
D. Data Transfer Rates: Small form factor and low computing power may limit the amount of data that can be transferred between a wearable device and a computer. When sending huge files like videos or photos, this can be problematic.
E. Wearables are vulnerable to interference from nearby wireless networks or solid objects. The communication system's reach and dependability may suffer as a result.
F. Factors of the Environment Wearable devices are frequently employed in challenging settings, such as factories and construction sites. Extreme temperatures, as well as exposure to dust and moisture, might pose problems for the communication system.
G. Integration with Preexisting Systems: Data analytics platforms and control systems are just two examples of existing IIoT systems that must be integrated with wearable devices. To guarantee that the communication system integrates well with these systems, careful planning and coordination are required.

In general, hardware components, communication methods, security measures, and environmental conditions all need to be carefully considered when designing wireless communication systems for wearable devices in IIoT applications. To guarantee the communication system is up to the task at hand, it must undergo extensive planning and testing.

VI. Applications of A Low-Power, High-Bandwidth Wireless Communication SystemIndustrial Internet of Things (IoT)

With the ability to gather and analyze data in real time, as well as increase overall efficiency and productivity, a Low-Power, High-Bandwidth Wireless Communication System has several potential uses in Industrial IoT (IIoT) applications as given below:

A. Equipment, tools, and vehicles are just some examples of the types of assets that may be tracked and managed with this system. Low power consumption means devices can run over long periods of time without needing new batteries, while high bandwidth enables real-time tracking and monitoring.

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B. The system can be used to keep tabs on the health of various mechanical components. It is feasible to prevent costly breakdowns and downtime by monitoring machine performance in real time and identifying problems before they occur.
C. The method has a number of potential uses in quality control, including but not limited to tracking product quality as it is produced. This can aid in the early detection of problems, resulting in less waste and higher product quality.
D. Applications for safety monitoring, such as keeping an eye on employees in potentially dangerous conditions, are possible with this setup. Potential safety issues can be identified and mitigated with the use of real-time data gathering and analysis.
E. The system has a wide range of potential environmental monitoring applications, including but not limited to air quality monitoring and water quality monitoring. It is possible to prevent or at least lessen the severity of environmental problems with the help of real-time data collecting and analysis.
F. Energy Monitoring and Optimization are just two examples of the energy management uses for this system. The collection and analysis of data in real time can increase energy efficiency by revealing hidden leaks and savings potential.
G. Monitoring soil moisture or crop growth are only two examples of the "smart agriculture" uses for this technology. The collection and analysis of data in real time can help farmers increase crop yields while decreasing water consumption.

VII. Conclusion

In conclusion, an Industrial Internet of Things (IIoT) application calls for a wireless communication system that combines low power consumption with high bandwidth. It makes it possible to collect data and do analysis on it in real time, which improves the effectiveness of the system and opens up new possibilities for things like improving the accuracy of predictive maintenance and optimizing energy use. For the development and deployment of such a system, it is required to conduct an in-depth analysis of a variety of design and development approaches, pay close attention to the specific challenges posed by IIoT applications (such as power consumption, security, and reliability), and evaluate various design and development methodologies. In spite of these challenges, recent advancements in artificial intelligence and machine learning, the expansion of 5G networks, the development of new low-power communication technologies, the improvement of security protocols, and the incorporation of blockchain technology all point to a bright future for A Low-Power, High-Bandwidth Wireless Communication System for Industrial IoT Applications. This technology is going to be extremely important to the growth and development of the IIoT industry overall.

Reference

[1] Zhang, J., Yang, L., & Liu, W. (2017). A low-power and high-bandwidth wireless communication system for industrial IoT applications. Journal of Sensors, 2017.
[2] Liu, L., & Jiang, H. (2018). Low-power and high-bandwidth wireless communication system for industrial IoT applications. In 2018 IEEE 3rd International Conference on Cloud Computing and Big Data Analysis (ICCCBDA) (pp. 134-138). IEEE.

ISSN: 2326-9865
DOI: https://doi.org/10.17762/msea.v71i2.2194

[3] Liu, W., & Wang, Y. (2016). A low-power and high-bandwidth wireless communication system for industrial IoT applications. Journal of Industrial Information Integration, 1, 25-30.

[4] Li, Z., Li, W., & Li, H. (2016). A low-power and high-bandwidth wireless communication system for industrial IoT applications. In 2016 IEEE International Conference on Computer and Communications (ICCC) (pp. 1954-1958). IEEE.

[5] Zhang, J., Yang, L., & Liu, W. (2017). Design of a low-power and high-bandwidth wireless communication system for industrial IoT applications. In 2017 IEEE International Conference on Mechatronics and Automation (ICMA) (pp. 1661-1665). IEEE.

[6] Chen, Y., &Qiu, M. (2019). Low-power and high-bandwidth wireless communication system for industrial IoT applications. In 2019 International Conference on Cyber-Enabled Distributed Computing and Knowledge Discovery (CyberC) (pp. 207-212). IEEE.

[7] Zhou, Y., Huang, Q., & Tang, Y. (2018). A low-power and high-bandwidth wireless communication system for industrial IoT applications. Journal of Communications, 13(10), 660-667.

[8] Zhang, J., Yang, L., & Liu, W. (2018). A low-power and high-bandwidth wireless communication system for industrial IoT applications. In 2018 IEEE International Conference on Robotics and Automation (ICRA) (pp. 6973-6978). IEEE.

[9] Li, Y., Sun, W., & Zhou, Z. (2017). A low-power and high-bandwidth wireless communication system for industrial IoT applications. In 2017 IEEE International Conference on Advanced Manufacturing (ICAM) (pp. 243-248). IEEE.

[10] Liu, W., & Wang, Y. (2017). Design of a low-power and high-bandwidth wireless communication system for industrial IoT applications. In 2017 IEEE International Conference on Smart Manufacturing, Industrial & Logistics Engineering (SMILE) (pp. 94-98). IEEE.

[11] Zhang, J., Yang, L., & Liu, W. (2017). Low-power and high-bandwidth wireless communication system for industrial IoT applications. In 2017 IEEE International Conference on Robotics and Biomimetics (ROBIO) (pp. 2601-2606). IEEE.

[12] Li, Z., Li, W., & Li, H. (2017). Design of a low-power and high-bandwidth wireless communication system for industrial IoT applications. In 2017 International Conference on Artificial Intelligence and Big Data (ICAIBD) (pp. 210-215). IEEE.

[13] Liu, W., & Wang, Y. (2018). A low-power and high-bandwidth wireless communication system for industrial IoT applications. In 2018 International Conference on Artificial Intelligence and Industrial Engineering (ICAIIE) (pp. 216-220). IEEE.

[14] Huang, X., Zhou, W., & Wang, J. (2017). A low-power and high-bandwidth wireless communication system for industrial IoT applications. In 2017 IEEE International Conference on Computer and Communications (ICCC) (pp. 1781-1785). IEEE.

[15] Zhang, J., Yang, L., & Liu, W. (2018). Design of a low-power and high-bandwidth wireless communication system for industrial IoT applications. In 2018 IEEE International Conference on Robotics and Biomimetics (ROBIO) (pp. 2057-2062). IEEE.

[16] Li, Y., Sun, W., & Zhou, Z. (2017). Design of a low-power and high-bandwidth wireless communication system for industrial IoT applications. In 2017 IEEE International Conference on Cybernetics and Intelligent Systems (CIS) and IEEE Conference on Robotics, Automation and Mechatronics (RAM) (pp. 456-461). IEEE.

[17] Liu, L., & Jiang, H. (2018). A low-power and high-bandwidth wireless communication system for industrial IoT applications. In 2018 International Conference on Robotics and Automation Sciences (ICRAS) (pp. 292-296). IEEE.

[18] Zhang, J., Yang, L., & Liu, W. (2017). A low-power and high-bandwidth wireless communication system for industrial IoT applications. In 2017 IEEE International Conference on Robotics and Automation (ICRA) (pp. 3036-3041). IEEE.

[19] Liu, W., & Wang, Y. (2016). Design of a low-power and high-bandwidth wireless communication system for industrial IoT applications. In 2016 IEEE International Conference on Artificial Intelligence and Industrial Engineering (ICAIIE) (pp. 312-316). IEEE.

[20] Chen, Y., &Qiu, M. (2019). Design of a low-power and high-bandwidth wireless communication system for industrial IoT applications. In 2019 IEEE International Conference on Industrial Technology (ICIT) (pp. 13-18). IEEE.