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Study on a Novel Network Nod Monitoring System based on the Spherical Multi-robot

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***Abstract* –The spherical multi-robot system is mainly used for water quality monitoring in large-scale aquaculture. The main research content of this article is how to realize the multi-robot system effectiveness of data transmission. Or, when the detection range is too large, the multi-robot system adopts the centralized control mode, once the instability of the central robot network occurs. If the data can not be fed back to the user, how to ensure the control ability of the entire multi-robot system. Novel network nod monitoring system has the advantages of Ad Hoc network, self - repair and not limited by the distance of router. It has been widely used in various fields. At the same time, cloud platform communication technology has also been widely used in the field of the Internet of Things. Its advantages are multi-purpose function, long transmission distance, strong safety performance, etc. By adopting self - owned cloud platform structure and the novel network nod monitoring system. It improves the flexibility and reliability of the multi-robot system and ensures the efficiency of large-scale data acquisition. In this paper, a Mesh network architecture and a network system based on cloud platform for spherical multi-robot systems are proposed. The experimental results show that it is feasible to construct the whole node monitoring system based on Mesh. With this system, the multi-robot system can accomplish more complex tasks.**

Index Terms –Meshnetworking, Data management, Multi-robot self-organizing team, Cloud server.

I. INTRODUCTION

Spherical multi-robot systems are mainly used to perform multiple tasks in specific environments. The number of water quality monitoring equipment manufacturers in China is growing rapidly. But the localization of the equipment is too low and the actual monitoring equipment is rarely used. And the problems of low technical grade, unstable performance, high failure rate and high cost commonly exist in domestic monitoring system and meters. General water quality monitoring is sampling back through electrolysis method, the cloud platform can be real-time monitoring, greatly improving the efficiency. Especially in civil aquaculture is difficult to achieve the task of comprehensive water quality detection.So in this study mainly through implementation of a spherical robot water quality on-line monitoring system for monitoring to obtain more detailed data.Such as PH, temperature, TDS value to record and save the data sent to the cloud platform, human communication and how to implement online more machines. Once the multi-robot conflict to transmit data to the clouds, how to ensure the efficiency of the multi-robot system to transmit data and packet loss, these are the main content of this paper studies[1].

Cloud platform as a new technology in the field of Internet of things, which can give users an unprecedented computing power, and a copy of the "cloud" to use the data more fault-tolerant. Compute nodes is omorphism interchangeable measures to guarantee services high reliability, scalability and reliable than using the local computer[2].

At present, there are cloud servers of Ali Cloud and Baidu Cloud servers in the market. In this study, Ali Cloud server was used.For the development and establishment of my own research, the development is carried out on Ali Cloud server, which also has high portability when switching servers, and the communication covers a long distance with good real-time performance.For this study, the delay of receiving data is milliseconds, so it is a necessary choice to choose the cloud platform as the intermediary of multi-robot communication[3].

Communication technology based on the cloud platform, this paper proposed the idea to spherical Mesh networking of multi-robot system, guarantee the multi-robot system in real time not losing packet communications[4]. At the same time, to realize the multi-robot automatic equipment replacement. Multi-robot group for implementation is proposed when the network is not stable solutions in the process of the judgment, and verifies the feasibility of multi-robot collaborative experiment in the experimental platform. At the same time, the cloud platform establishes the database and carries out MAC verification on the equipment to better protect the multi-robot water quality monitoring system, avoid the intrusion of the monitoring system, and better preserve the data as a reserve[5] for the subsequent pollution analysis. Finally, the application prospect of novel network nod monitoring system to multi-robot system is discussed.

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II. The Platform of Spherical Multi-robot System

The four steering wheels under the ball are mainly used in land walking mode. According to the PWM speed control to control the motor forward how many steps and each step is how big, that is to control its speed. When underwater, they are powered by water jets. Since the background of this research is aquaculture water quality monitoring, the water jet propulsion system of the research platform is introduced.Water jet propulsion system is a new type of special power device. Different from ordinary propellers, the thrust of water jet propulsion is generated by the reaction of the propulsion pump to the water jet [6].

Robots usually work in specific environments [7], including land and underwater, and work in specific ways. Such as patrol, monitoring and military operations. For multi-robot, cooperation is the best working mode of swarm robot. And this working mode undoubtedly increases the difficulty of communication and control, the required communication range will also expand, and the control should also enhance the reliability.

The spherical multi-robot system[8] needs to realize wireless communication and expand the range of multiple times to ensure real-time communication and anti-aggression. The realization of these functions has important practical significance. At the same time, as an application of water quality monitoring, if the data is too concentrated in a team central robot, the risk of packet data loss will occur due to network or intruders. Once the root robot goes offline, the whole group of multi-robots[9] will suffer a large-scale packet loss phenomenon. Therefore, not only decentralization, but also no loss of packets should be achieved[10]. That is to say, the team leader should be changed according to the strength of the signal of the equipment[11]. The team leader is strongest signal.Our spherical multi-robot platform is shown in fig. 1.

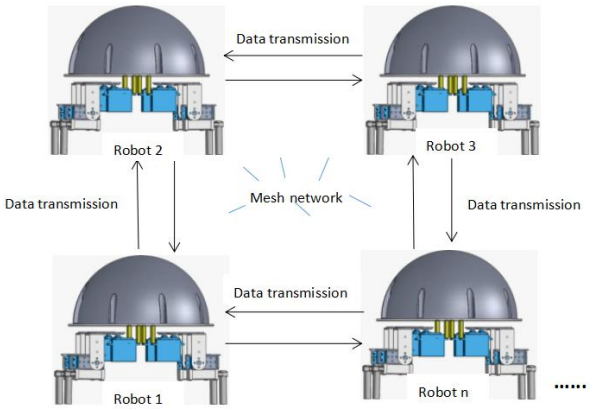

Fig. 1 The conceptual diagram for multi-robot communication.

In the third section, mainly describes the structures, the cloud platform, based on the cloud platform for communication and completion port open, and other functions. In the fourth part, mainly discuss the cloud servers attack against external devices and the server verifies the public[12], in the fifth part, describes the design of the Mesh network. In the sixth part, to make the actual experiment proofs on Mesh network can be used for the spherical robot to work together in the water quality monitoring.

When all the devices are successfully networked, they will enter the network node monitoring system. The child nodes continue to compete, changing nodes as the network grows stronger. Finally, after successful connection, real-time monitoring will be carried out by the cloud platform. It is shown in fig. 2 below on the network nod monitoring system.

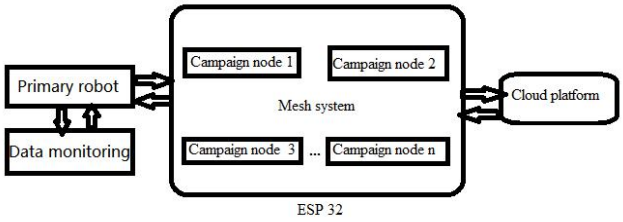

Fig. 2 Network nod monitoring system.

III. Building Cloud Platform

A. Cloud platform technology

As the most popular cloud computing platform at present, cloud platform also plays a maximum role in application. It can create and manage large and complex IT infrastructure (including virtual server, network, application, storage equipment, etc.) in a fast, simple and extensible way. The communication coverage can be controlled, as long as there is network coverage. It can realize communication [13], users only need to send a request through the network can get the required resources from the cloud to the local pen, all the computing tasks are completed in the remote cloud data center. The reason why users can obtain a variety of computing services, storage services and software resources on demand is because of the powerful virtualization resource pool architecture of cloud computing. The resource pool in the data center itself can not only be dynamically expanded. But also the resources can be recycled timely and conveniently after users have finished using them. Such service delivery mode greatly increases the resource utilization of cloud data center. And cloud computing service providers can also better improve the quality of service.

However, if you just buy an account of Alibaba's cloud server, there will be many restrictions on the development voucher. Such as how to achieve cross-platform[14] and cross-service providers in the cloud service, that is to say, the service providers have to balance the development function and compatibility. Early cloud computing provided APIs that were far more restrictive than traditional service systems such as databases.The code is not common across service providers, which puts a lot of programming burden on cross-platform developers.

Therefore, we need to build an experimental cloud platform of our own. So that programming will not have too many restrictions, and we can open the required ports and functions specifically. And the data can be better protected in the data storage and feedback, which is very important for the reliability and security of the experiment.

B. Server setup process

The first is Tomcat Web server[15] setup, which is required as an important configuration on your own cloud server. Because Tomcat advanced technology, stable performance, and free, and get the recognition of some software developers.So it is a lightweight application server among the more popular Web[16] application servers.Especially in small and medium-sized systems and users concurrent access is not often used, is the development and debugging of the first choice of JSP applications.Think of it as an Apache server that, once configured on the machine, can be used to respond to requests for access to HTML(an application in the Standard Generalized Markup Language) pages. The Web server is mainly used to serve HTTP requests. In this research experiment, it is used to authenticate the device and APP. And the device or APP can access the server with ID or account password through HTTP POST requests [17]. The establishmentindicates that the construction is successful and can be used normally. The Tomcat server is set up to represent the server with the ability to process HTML pages. And it is also a JSP container, which makes it easier to stabilize and develop our server.The overall setup process is shown in the fig. 3.

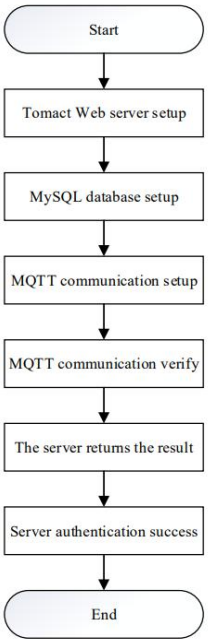

Fig. 3 Server Setup Process.

Next comes MQTT message server setup and IoT communication validation.MQTT is a client-server based message publish/subscribe transport protocol. It is lightweight, simple, open, and easy to implement, which makes it applicable to a wide range of applications.In many cases, including in restricted environments such as machine-to-machine (M2M) communication and the Internet of Things (IoT). It can be used to establish channels for data transmission [18].In this study, we need to build its message server to pave the way for communication transmission. Only after the road is repaired, can the data be guaranteed to reach the cloud server. Since the robot visits with its own ID, a database needs to be set up to store the individual IDs of the group of spherical robots. The MySQL database setup is necessary.

You need to verify in the server background that the MQTT server is working properly. When the device in the data table connects to the server, it will be fed back with the corresponding user name and password. So that it can log in and view the MQTT background program. The entry of the device is displayed in green, which represents the successful MQTT setup.

Once the database is set up, the messaging server is set up. Communication protocols communicate with remote sensors and control devices over low-bandwidth, unreliable networks and provide one-to-many messaging. After the MQTT message server is built, the background interface displays the logon status of groups of robots when they are accessed using their IDs. For example, green means logged in and red means off the network.

After the Tomcat Web[19], MySQL database, and MQTT communication channels are set up. They can be opened on their own cloud server and configured to open the server firewall ports (providing access to the outside world) so that IOT communication can be verified. The data received by the cloud server is completely consistent with the data collected. Indicating that the communication is successful. After the form is established, the MAC address of the device and its corresponding user name and password can be entered in it to determine whether the device can enter the server.

IV. Making a Public Network Authentication Request

Public network authentication performed by cloud servers is a form of SSL digital certificates. It is used to prove the identity of the visitor or to indicate that the visitor has access to the online service. In simple terms, server certificates can be used to provide authentication for different sites and ensure strong encryption security for sites [20]. However, not all sites need to add a server certificate. In this study, it involves the interaction between the spherical cluster device and the server connecting machine, including the contents such as passwords and private data pages. In order to keep the device and user data secure and confidential, we need to apply for server security authentication.

The server certificate obtained contains detailed authentication information. Such as the organization that the server content is attached to, the organization that issued the certificate, and a unique authentication file called a public key. This means that the server certificate ensures that the user is authenticated with respect to the content of the Web server. And it means that the established HTTP connection is secure and not vulnerable to fraudulent phishing sites.

First of all, we need to establish a user operation table in the established MySQL database, add two test data (202120210001, 202120210002) to it. Write its MAC address and corresponding password [21], and use the two data to carry out authentication service. Next, an HTTP authentication request is made using the browser, and when two test data are entered in the database, the corresponding

correct feedback is obtained. However, when data is not entered in the table, the server will return the data result as "0" (i.e., return the failure information).

When accessing the server, the device not only brings its ID, but also its password to visit. In order to avoid the password being stolen by phishing websites during the visit[22]. We use a SHA256 encryption algorithm to ensure the security of user data on the public network. SHA256 is a hash function, also known as a hash algorithm, which is a way to create small digital "fingerprints" from any kind of data. The hash function compacts the message or data into a summary, reducing the amount of data to a fixed format. This function scrambles the data and recreates a fingerprint called a hash value (or hash value), which is typically represented by a short, random string of letters and numbers. The password carried by the device is processed by the SHA256 encryption algorithm, which generates a 256-bit hash. A series of logical operations, including addition, subtraction, multiplication and division, turns the password string into a complex string. So that phishing sites can't directly steal account information.

After debugging the authentication service, Ali Cloud is packaged and deployed, WAR package is uploaded and public network access is provided to the outside world. After successful uploading, the website will display the server IP and MAC address of the authentication device.

After the success of public network authentication, the message server and HTTP security authentication of the whole platform are basically deployed. When a website is attacked, It has the ability to resist, and records which servers are attacked and the attack time. This basic authentication allows a Web browser or other device-side program to provide credentials for a user name and password on request for login authentication.

V . MESH NETWORK DESIGN AND APPLICATION

The principle of novel network nod monitoring system in routers is that Mesh clients are connected to wireless Mesh routers through wireless connection. The wireless Mesh routers form a relatively stable forwarding network in the form of multi-hop interconnection. In the general network architecture of WMN, any Mesh router can be used as the data forwarding and relay of other Mesh routers.

We want to collect data with high efficiency and high standards. Generally, water quality tests are conducted by sampling back through electrolysis method, etc. However, if our robot group adopts novel network nod monitoring system to collect data, the online water quality detection ability is strengthened. And the collaboration ability of the robot group is improved. The gateway Mesh router forwards the traffic between the WMN and the Internet through a high-speed wired link.

The general network architecture of WMN can be seen as consisting of two planes. The WIMN access plane provides a network connection to the root node. Now let's assume that there are two devices on the root node and that the entire Mesh network runs after success. See fig. 4.

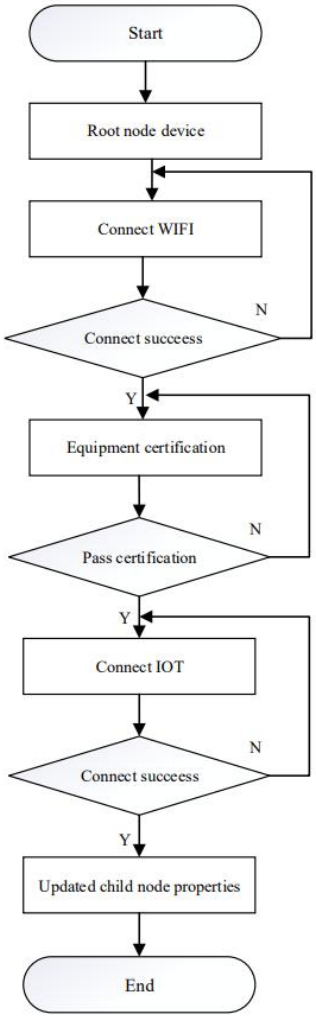

Fig. 4 Mesh operational process.

A. *The idea of extracting the root node*

Novel network nod monitoring system is mainly used in wireless routers. When the required network coverage area is large, the WiFi coverage range of a router may not be enough and the signal will be much worse. By using Mesh networking, connections can be established between several routers, so that the WiFi coverage range becomes the superimposed range of these routers.

Then the user's mobile phone will always automatically connect to the router with the best signal. This is the basic principle of Mesh networking. Now we have two devices A and B competing for the root node. Let's take A look at the specific competition process, as shown in fig. 5 and fig. 6.

In this study the robot in real time water quality detection is a network connection, so the equipment to maintain the best in the signal. Used in mesh networks, it can greatly improve the reliability of cloud platforms and user data transmission. When the signal of the equipment is weak, change the captain in time, rather than completely destroy the data loss to make the corresponding action. The network architecture ensures team coordination.

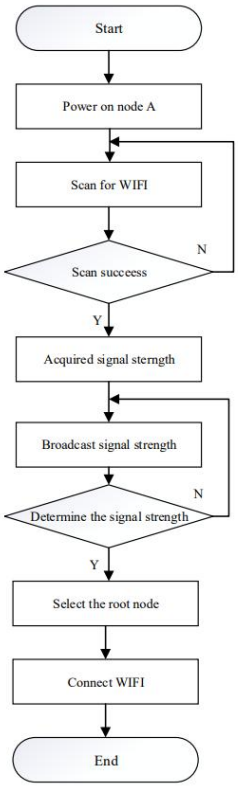

Fig. 5 Node A runs the procedure.

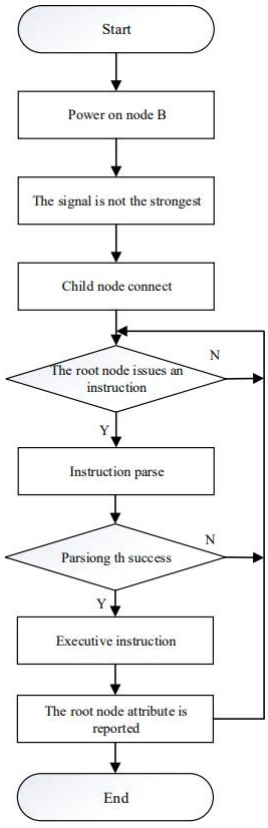

Fig. 6 Node B runs the procedure.

B. The novel network nod monitoring system running

What we need to choose is the Mesh connection and pathfinding thought novel network to improve the stability of network and data transmission of the group of spherical robots. The root node (leader) is determined according to the network signal strength of each device. All nodes are connected together, and there are multiple connection channels between any two nodes, which show an obvious decentralization trend. This kind of decentralization is different from replacing the root node after dropping the line. The way that the root node is not destroyed is that the root node can be automatically replaced at any time according to the network signal strength, and no data will be lost.

Chose a Mesh instead of the ordinary in the design of the 4g or NBIOT passthrough module mainly is for the sake of system stability and economic cost. Mesh can be used to complete the ad-hoc network, self-healing, large covering area. The advantages of minimal bandwidth, only need one device is connected to the robot cluster user router robot can complete the entire cluster of collecting, reporting and control, and so on. The AD hoc network technology is illustrated in the following table1.

TABLE I

AD HOC NETWORK TECHNOLOGY COMPARISON DIAGRAM

	Node(n)	Distance(m)	Rate
Zig Bee	200	100	300Mbps
Lora	200	100	37.5Mbps
WI-FI Mesh	200	100	600Mbps

When the firmware is burned successfully to ESP32, the serial port log will be displayed successfully accordingly. The Mesh was started successfully. The system then enters the root node campaign mode, where the nodes run continuously and perform the node run process shown in the figure above.

C. Verification in multi-machine collaborative system

On the basis of the spherical robot platform, the multi-device in the mesh network is the multi-machine crowd. Now use multiple robots to simulate. First of all, fig. 7 shows the change of equipment network entry and networking with the number of devices. When the monitoring network is running, the system can greatly reduce the data packet loss rate and Improve the real-time performance of data transmission. When the root node wins the election. It will receive the IoT control command and broadcast the command to other nodes throughout the mesh network[23].

The abscissa is the number of devices, the unit is ***p***; the ordinate is time, the unit is ***s***. This curve reflects the comparison of the time when the number of robots on different nodes is added to the Mesh system. Although the number of devices increases, the network time will increase, but the data transmission and automatic pairing will not have a significant impact.

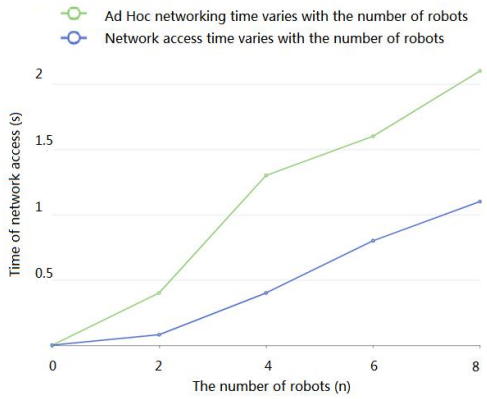

Fig. 7 Network formation and network entry time transformation diagram.

VI. Conclusions and Future Work

This paper proposed a new type of decentralized network system. The system was mainly used in large-scale aquaculture water quality monitoring. In the existing network system, when a fixed central node is used by multiple devices, the availability of the communication network of the central node is greatly reduced. The core nodes of the novel network nod monitoring system, each node is very simple, and this problem does not occur. Although in this study, the number of robots groups used in the experiment is not large. However, in the multi-robots human application, the monitoring system network system can expand the number of multi-robot. The system solves the network instability of water quality monitoring and the real-time and effectiveness of data transmission.

In recent years, monitoring network have only been used for router commercialization. In this paper, it is applied to multi-robot collaboration to solve the problem that central robot is affected by network. In the future application, the network security of the system needs to be strengthened.

Acknowledgments

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Reference

[1] Y. Liangyan, L. Jing, Z. Xuedong, and X. Ming, "Research on personalized virtual training room for cloud computing technology and application specialty", *Journal of Anhui Vocational College of Electronics & Information Technology*, vol. 11, no. 3, pp.21–23, 2019.

[2] Shelly Shiju George, "A review of different techniques in cloud computing", *Materials Today: Proceedings*, vol. 26, no. 1, pp.116-121, 2019.

[3] F. Ling, "Construction of personalized network learning system based on cloud computing environment", *Information System Engineering*, vol. 7, no. 7, pp.23–23, June 2018.

[4] Richard Klophaus. "Mesh network as a competitive advantage for European LCCs: An alternative topology to hub-and-spoke for selling online connections" *Transport Policy*, vol 106, pp.196-204, June 2021.

[5] C. Yuwei, et al, "A quadratic voltage model for optimal power flow of a class of meshed networks", *International Journal of Electrical Power & Energy Systems*, vol. 131, no. 11, pp.158-167, October 2021.

[6] S. M. Darroudi and C. Gomez, "Modeling the Connectivity of Data-Channel-Based Bluetooth Low Energy Mesh Networks," *IEEE Communications Letters*, vol. 22, no. 10, pp.2124-2127, Oct. 2018.

[7] Jian Guo, Shuxiang Guo, et al, "Design and Characteristic Evaluation of a Novel Amphibious Spherical Robot", *Microsystem Technologies*, vol.23, no.6, pp. 1-14, 2017.

[8] S. Pandi, S. Wunderlich and F. H. P. Fitzek, "Reliable low latency wireless mesh networks — From Myth to reality," *2018 15th IEEE Annual Consumer Communications & Networking Conference (CCNC)*, pp. 1-2, January 2018

[9] Shuxiang Guo, Yanlin He et al, "Modal and fatigue analysis of critical components of an amphibious spherical robot", *Microsystem Technologies*, vol.23, no.6, pp.1-15, 2016.

[10] Maoxun Li, Shuxiang Guo, et al, "Design and performance evaluation of amphibious spherical robot", *Robotics and Autonomous Systems*, vol.64, no.6, pp.21-34,2018.

[11] Liang Zheng, Shuxiang Guo, et al, "The communication and stability evaluation of amphibious spherical robots", *Microsystem Technologies*, vol.24, no.6, pp.1-12, 2016.

[12] Yanlin He , Shuxiang Guo, et al, "Preliminary Mechanical Analysis of an Improved Amphibious Spherical Father Robot", *Microsystem Technologies*, vol.22, no.8, pp.2051-2066, 2016.

[13] Shuxiang Guo, Shaowu Pan, et al, "A system on chip-based real-time tracking system for amphibious spherical robots", *International Journal of Advanced Robotic Systems*, vol.14, no.4, pp.1-9, 2018.

[14] H. Lee and K. Ke, "Monitoring of Large-Area IoT Sensors Using a LoRa Wireless Mesh Network System: Design and Evaluation," *IEEE Transactions on Instrumentation and Measurement*, vol. 67, no. 9, pp. 2177-2187, Sept. 2018.

[15] H. Fujinaka, T. Ohta and Y. Kakuda, "Evacuation Route Guidance Scheme for Building Evacuation Using Wireless Mesh Network Systems," *2020 Eighth International Symposium on Computing and Networking Workshops (CANDARW)*, pp. 8-13, 2020.

[16] X. Jiang et al, "Hybrid Low-Power Wide-Area Mesh Network for IoT Applications," *IEEE Internet of Things Journal*, vol. 8, no. 2, pp. 901-915, 15 Jan.15, 2021.

[17] C. Garrido-Hidalgo, D. Hortelano, L. Roda-Sanchez, T. Olivares, M. C. Ruiz and V. Lopez, "IoT Heterogeneous Mesh Network Deployment for Human-in-the-Loop Challenges Towards a Social and Sustainable Industry 4.0," *IEEE Access*, vol. 6, pp. 28417-28437, 2018.

[18] K. Haseeb, I. Ud Din, A. Almogren, N. Islam and A. Altameem, "RTS: A Robust and Trusted Scheme for IoT-Based Mobile Wireless Mesh Networks," *IEEE Access*, vol. 8, pp. 68379-68390, 2020.

[19] Q. Chen, X. J. Zhang, W. L. Lim, Y. S. Kwok and S. Sun, "High Reliability, Low Latency and Cost Effective Network Planning for Industrial Wireless Mesh Networks," *IEEE Transactions on Networking*, vol. 27, no. 6, pp. 2354-2362, Dec. 2019.

[20] S. Kafaie, Y. Chen, O. A. Dobre and M. H. Ahmed, "Joint Inter-Flow Network Coding and Opportunistic Routing in Multi-Hop Wireless Mesh Networks: A Comprehensive Survey," *IEEE Communications Surveys & Tutorials*, vol. 20, no. 2, pp. 1014-1035, January 2018.

[21] A. Karaagac, E. De Poorter and J. Hoebeke, "In-Band Network Telemetry in Industrial Wireless Sensor Networks," *IEEE Transactions on Network and Service Management*, vol. 17, no. 1, pp. 517-531, March 2020.

[22] Di Felice, et al. "Self-organizing aerial mesh networks for emergency communication." *IEEE 25th Annual International Symposium on Personal, Indoor, and Mobile Radio Communication (PIMRC)*, pp.1631– 1636,2018.

[23] R. Pirmagomedov, "Facilitating mmWave Mesh Reliability in PPDR Scenarios Utilizing Artificial Intelligence," IEEE Access, vol. 7, pp. 180700-180712, 2019.