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International Journal of Research in Engineering and Applied Sciences(IJREAS)
Available online at http://euroasiapub.org/journals.php
Vol. 13 Issue 10, October -2023,
ISSN(O): 2249-3905, ISSN(P) : 2349-6525 | Impact Factor: 8.202| Thomson Reuters ID: L-5236-2015

A STUDY ON INDUSTRIAL IOT PROTOCOLS AND COMMUNICATION STANDARDS FOR OPTIMIZING PERFORMANCE AND INTEROPERABILITY IN ROBOTIC SYSTEMS

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ABSTRACT:

For the purpose of promoting operational efficiency and interoperability across a variety of production contexts, the increasing integration of protocols and communication standards for the Industrial Internet of Things (IIoT) in robotic systems has become an essential component. The efficiency of various protocols for the IIoT is being evaluated in order to ascertain the impact that these protocols have on the speed of data transmission, dependability, and system integration. This is happening as industries attempt to find solutions for automation and smart manufacturing. By conducting research on industrial internet of things protocols and communication standards for the purpose of optimising performance and interoperability in robotic systems, the primary objective of this study is to learn more about these topics. In the course of this research, a qualitative approach was utilised as the methodology. This research analyses the possibilities and limitations of these protocols in terms of supporting seamless communication between heterogeneous robotic systems and other Internet of Things devices. The results of the study reveal that particular protocols considerably increase the responsiveness of the system as well as the accuracy of the data while simultaneously assuring robust interoperability among various robotic platforms.

Keywords: IIOT; Protocols; Communication Standards; Performance; Interoperability.

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INTRODUCTION:

The swift advancement of the IIoT has profoundly altered contemporary manufacturing and automation, necessitating the enhancement of performance and interoperability of robotic systems. In this context, numerous communication protocols and standards have developed to enable seamless data sharing and integration across various robotic devices and other IoT components (Behnke & Austad et al., 2023). This study seeks to evaluate the efficacy of IIoT protocols, including "MQTT (Message Queuing Telemetry Transport), CoAP (Constrained Application Protocol), and OPC UA (Open Platform Communications Unified Architecture)," in improving the operational efficiency and connectivity of robotic systems. The implementation of advanced robotics in industrial environments necessitates dependable and prompt communication among machines, sensors, and control systems to provide real-time data processing and decision-making. The diverse characteristics of these systems present considerable issues with interoperability, data integrity, and latency (Hazra et al., 2021; Jaloudi, 2019; Vermesan et al., 2019).

The principal objective of this study is to assess and contrast several IIoT communication protocols to discern their advantages and disadvantages in enhancing performance indicators, including throughput, reaction time, and energy efficiency. The study aims to comprehensively analyse the contribution of these protocols to the interoperability of robotic systems, offering significant insights for manufacturers and system integrators in choosing suitable communication standards that meet their operational needs. The findings seek to facilitate the introduction of more integrated and effective robotic solutions in the industrial sector, promoting creativity and productivity in a progressively interconnected world. The literatures that have been previously related to this study are discussed in the next section.

LITERATURE REVIEW:

The following table provides an overview of the previous literature concerning industrial internet of things protocols and communication standards with the purpose of optimising performance and interoperability in robotic systems respectively.

Table 1: Related Works

AUTHORS AND YEAR	METHODOLOGY	FINDINGS
Kabanov & Kramar (2022)	Conducted a comprehensive review of existing marine IoT platforms, focusing on their architectural designs and interoperability features for marine robotic agents	The study identified key architectural components and interoperability mechanisms that enhance the collaboration and integration of marine robotic systems, highlighting the potential for improved operational efficiency and data sharing in maritime environments.
Ladegourdie & Kua (2022)	A systematic performance analysis of the "OPC UA (Open Platform Communications Unified Architecture)" protocol by conducting experiments to evaluate its scalability, response time, and data throughput in various industrial scenarios simulating Industry 4.0	The findings demonstrated that OPC UA effectively supports interoperability in industrial settings, showing robust performance metrics that facilitate real-time communication and data exchange among diverse manufacturing systems, thereby contributing to the seamless integration

	environments.	necessary for Industry 4.0 advancements.
Soori et al., (2024)	The authors conducted a comprehensive literature review of existing intelligent robotic systems within the context of Industry 4.0, analyzing various technologies, applications, and frameworks to identify trends, challenges, and advancements in the field.	The study concluded that intelligent robotic systems significantly enhance manufacturing processes through improved automation, adaptability, and data-driven decision-making, while also highlighting the need for further research on interoperability and integration challenges to fully realize their potential in Industry 4.0.

Research Gap: The research gap in assessing Industrial IoT protocols and communication standards is characterised by the absence of thorough comparative studies evaluating the performance and interoperability of diverse protocols, particularly inside robotic systems. Moreover, current literature frequently neglects the practical ramifications of these protocols in actual production contexts, hence requiring a targeted examination to ascertain how various standards might be effectively applied to improve the efficiency and integration of robotic systems.

METHODOLOGY:

Utilizing secondary data derived from pre-existing literature, reports on the sector, and individual cases, this study utilizes a qualitative research style pertinent to Industrial IoT protocols and communication standards. The paper systematically analyses and compares the performance metrics, interoperability features, and implementation issues of several protocols, including MQTT, CoAP, and OPC UA, within the framework of robotic systems. Moreover, professional analyses and perspectives from pertinent industry publications are incorporated to furnish a thorough comprehension of the actual ramifications of these procedures on augmenting robotic system efficiency and integration.

RESULTS AND DISCUSSIONS:

This study focusses on the integration of modern communication frameworks in the developing field of industrial automation. As industries evolve towards Industry 4.0, the significance of the IoT in improving operational efficiency, productivity, and collaboration across robotic systems escalates. This investigation entails comprehending diverse protocols and standards that regulate communication among distinct equipment and systems, thereby facilitating seamless interactions and enhanced performance in manufacturing settings.

The IIoT denotes the connectivity of industrial devices and systems over the internet, facilitating data sharing and remote surveillance. This technology enables improved automation, predictive maintenance, and real-time data analytics, converting conventional industrial processes into more intelligent and efficient operations. Robotic systems are essential, functioning as the foundation of automated operations that demand accuracy, rapidity, and adaptability. The efficacy of these robotic systems depends on their capacity for effective communication with other devices, sensors, and control systems, rendering the selection of protocols and communication standards essential (Soori et al., 2024).

Protocols are crucial for facilitating communication among devices in a network, dictating the methods of data transmission, reception, and processing. In industrial automation, the use of standardised communication protocols is essential for assuring compatibility and interoperability across various equipment from different manufacturers. Diverse protocols possess distinct strengths and disadvantages that can substantially influence the performance and scalability of robotic systems.

Some of the commonly used IIoT protocols include:

1. **“MQTT (Message Queuing Telemetry Transport)**:” Message Queue Telemetry Transport (MQTT) is a low-bandwidth, high-latency transmission protocol. Internet of Things (IoT) devices often use it because of how effectively it works for global controlling and monitoring, including robotic systems. Its publish/subscribe architecture allows for efficient data transmission and reduced network congestion.
2. **“CoAP (Constrained Application Protocol)”**: CoAP is a specialized protocol for constrained devices and networks. It is designed to enable simple, efficient communication in resource-limited environments, making it suitable for applications in which devices have limited processing power or memory. CoAP’s ability to handle RESTful interactions aligns well with the needs of IoT systems.
3. **“OPC UA (Open Platform Communications Unified Architecture)”**: One such interoperable standard is OPC UA, which establishes guidelines for safe and dependable data transfer across various devices and devices. It offers a robust solution for industrial automation, enabling different devices, including robotic systems, to communicate seamlessly while ensuring data integrity and security.

The optimization of performance in robotic systems involves enhancing several key metrics, including data throughput, latency, reliability, and energy efficiency. By selecting the appropriate communication protocol, manufacturers can significantly improve the operational efficiency of their robotic systems. For instance, protocols that support high data rates and low latency are critical for real-time applications where rapid decision-making is essential. Interoperability is another critical aspect that influences the effectiveness of robotic systems in an industrial setting. As production environments become increasingly heterogeneous, with devices from different manufacturers, the ability of these systems to work together seamlessly is crucial (Vermesan et al., 2020). Communication standards that promote interoperability enable robotic systems to integrate with various sensors, actuators, and control systems, fostering collaboration and flexibility in manufacturing processes.

The exploration of IIoT protocols and communication standards has significant implications for the future of industrial automation. As industries adopt more advanced technologies, understanding the strengths and limitations of different communication frameworks will be essential for optimizing robotic system performance. Moreover, the study of these protocols will inform manufacturers about best practices for implementing integrated solutions that enhance productivity and reduce operational costs.

CONCLUSION:

In conclusion, this study reflects a vital area of research that addresses the integration of advanced communication technologies within industrial automation. By evaluating various protocols and standards, this research contributes to the ongoing effort to improve the efficiency, flexibility, and responsiveness of robotic systems in the evolving landscape of Industry 4.0, ultimately driving innovation and competitiveness in the manufacturing sector.

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