DOI: 10.35598/mcfpga.2026.019

Principles of Information Interaction Organization for Automated Warehouse Transport in the IIoT

Yevhenii Shalko
ORCID 0000-0001-9864-6990
Department of computer-integrated technologies, automation, robotics and safety engineering
Kharkiv National University of Radio Electronics
Kharkiv, Ukraine
yevhenii.shalko@nure.ua

***Abstract*—This article examines the principles of organizing information interaction for automated warehouse transport within the framework of the Industrial Internet of Things (IIoT) concept. It is shown that modern warehouse transport systems, such as AGVs and AMRs, should be viewed not as isolated technical devices, but as nodes of a unified cyber-physical infrastructure connected to a dispatch server, WMS, operator interfaces, and an analytical layer. The main principles for establishing such interaction are identified: hierarchy, real-time operation, standardized data exchange, reliability and fault tolerance, scalability, and the security of information exchange. A generalized conceptual diagram of data exchange between a vehicle, an IIoT gateway, a control server, and a warehouse information system is proposed. It is demonstrated that high-quality information interaction is a fundamental prerequisite for coordinating transportation, reducing downtime, improving traffic safety, and facilitating the transition to intelligent management of traffic flows in warehouse systems.**

Keywords—IIoT, warehouse automation, AGV, AMR, information interaction, fleet management, warehouse transport

I. Introduction

The automation of warehouse systems is one of the most prominent areas of digital transformation in logistics. In modern warehouses, automated guided vehicles (AGVs) and autonomous mobile robots (AMRs) are increasingly being used to transport pallets, containers, and picking units. AGVs typically operate according to predefined movement rules, whereas AMRs have a higher level of autonomy, are capable of making decisions locally, and do not require a rigidly defined navigation infrastructure. At the same time, in both cases, operational efficiency is determined not only by the mechanical components of the vehicle but, above all, by the quality of data exchange between the vehicle, the dispatch system, the WMS, and the human operator. [1]

The IIoT concept provides the foundation for building a unified information infrastructure in which sensors, controllers, mobile robots, servers, and application systems function as interconnected components. In such an architecture, interoperability, secure data exchange, support for multi-level interaction, and the ability to work with data at both the peripheral and enterprise service levels are crucial. In the context of Industry 5.0, this infrastructure should not only increase productivity but also support a human-centered approach, sustainability, and the adaptability of production and logistics processes. The purpose of this article is to define the basic principles for organizing the information interaction of automated warehouse transport within the framework of the IIoT concept. [2]

II. Problem Statement

Automated warehouse transport operates in a shared space where other robots, forklifts, stationary equipment, and personnel are present simultaneously. Under such conditions, movement routes can change dynamically, and the transport system must continuously receive data on current position, task status, battery charge, obstacles, and the accessibility of warehouse zones. For practical operation, this is insufficient at the level of an individual robot: synchronization with the WMS, planning tools, task queues, and resource allocation mechanisms is required. Disruptions in information exchange in such an environment lead not only to delays in order fulfillment but also to route conflicts, inefficient downtime, outdated commands, and potentially dangerous situations. Therefore, without high-quality information exchange, automated transport cannot function effectively as a fully-fledged part of the warehouse system. [3]

III. Automated Warehouse Transport as an Element of an IIoT System

Within the IIoT framework, AGVs or AMRs should be viewed as cyber-physical nodes that integrate the sensor level, actuators, a local controller, embedded navigation algorithms, a communication module, and external interaction services. At the local level, the vehicle generates data on coordinates, speed, mission status, technical condition, the presence of obstacles, and power supply parameters. This data is then transmitted via the network infrastructure to a control server or IIoT platform, where it is combined with information from the WMS, monitoring systems, and operator interfaces. It is precisely this multi-level architecture that ensures interoperability, scalability, and coordination between physical transport processes and the warehouse's information loop. For industrial scenarios, platform independence, hierarchical data representation, event subscription, auditing, authentication, and support for both client-server and publish/subscribe exchange are particularly important. [4]

IV. BASIC PRINCIPLES OF ORGANIZING INFORMATION INTERACTION

A. *The Principle of Hierarchy*

It is advisable to organize information interaction across several levels: the local vehicle level, the fleet management level, the warehouse information system level, and the analytics level. This approach distinguishes between operational responses and strategic decisions. For example, a local stop upon detecting an obstacle should be executed on board the vehicle, while rescheduling the task queue should occur at the dispatch or WMS level. This reduces the load on the central server and improves system stability. [5]

B. *Real-time operation principle*

For critical events, data exchange must have minimal latency. Such events include emergency stops, detection of a person or obstacle in the travel zone, trajectory conflicts, route changes, and failure notifications. Next-generation industrial networks consider low latency, reliability, and determinism to be fundamental requirements for robots and transport systems in manufacturing and warehouse environments. [6]

C. *The Principle of Standardized Data Exchange*

Information exchange must be based on unified message structures, formalized data models, and agreed-upon semantic rules. This makes it possible to integrate transport systems from different manufacturers with WMS, ERP, SCADA, or analytics services without an excessive number of individual integrations. In practice, this means using common object identifiers, a single status model, unified events, and standard mechanisms for subscribing to status changes. [4]

D. *The Principle of Reliability and Fault Tolerance*

An information exchange system must remain operational even in the event of partial failures. This requires retransmission of critical messages, command buffering, local storage of the last valid state, switching to a safe mode in the event of a communication loss, and redundancy for critical communication channels. This is particularly important for warehouse transportation, as a communication failure coincides with the physical movement of cargo and can affect both productivity and safety. [7]

E. *The Principle of Scalability*

The data exchange architecture must not lose manageability as the number of vehicles, warehouse zones, or types of technological equipment increases. Initially, the system may serve a single AGV, then a group of AGVs/AMRs, and later several logistics zones with different priorities and varying traffic densities. Accordingly, the information interaction model must support horizontal scaling of the fleet and the integration of new services without a complete redesign of the system's core.

F. *Security Principles for Information Interaction*

For control commands, telemetry, and event logs, the following are required: access control, data source verification, protection against duplicate or outdated commands, auditing, and logging. In practice, this means node authentication, message integrity verification, differentiated access rights for the operator, server, and vehicle, as well as the ability to trace the cause of every critical action in the system.

V. GENERALIZED DIAGRAM OF INFORMATION INTERACTION

In general, the information loop of an automated warehouse transport system can be represented as a chain: vehicle sensors → local controller → communication module → ana

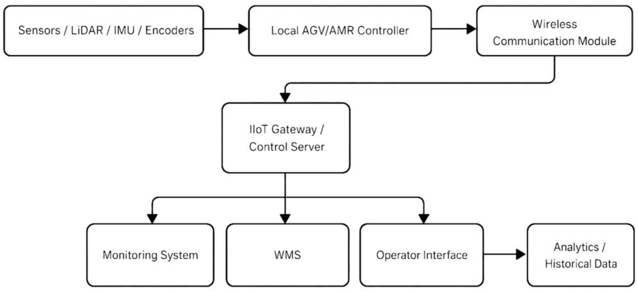

Fig. 1. Conceptual Architecture of Information Interaction for Warehouse Transportation in IIoT

In the reverse direction, missions, priorities, route correction commands, zone access restrictions, and signals to switch to safe mode are transmitted. This organization ensures both local autonomy and system-wide coordination (Fig

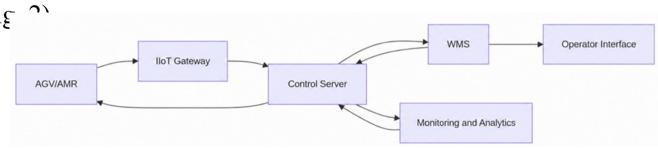

Fig. 2. Data flow between warehouse transport and the warehouse information system

VI. ADVANTAGES AND LIMITATIONS OF IIOT-ORIENTED INTERACTION

The use of IIoT for warehouse transportation enables centralized monitoring of the vehicle fleet, rapid response to changes in the operational situation, better route coordination, reduced downtime, and data collection for further analysis. In addition, the combination of telemetry, events, and technical condition logs creates a foundation for diagnostics, failure prediction, and the refinement of fleet management algorithms. In this regard, IIoT serves as a technological bridge between operational management and future models of intelligent warehouse flow management. Along with these advantages, there are also significant limitations. These include the instability of wireless communications, delays in transmitting critical messages, the complexity of integration with existing WMS solutions, the heterogeneity of data formats across different manufacturers, dependence on the quality of sensor data, and the need for enhanced cybersecurity. Therefore, IIoT implementation is not merely a matter of connecting vehicles to the network. It requires systematic design of the information architecture, where parameters such as latency, reliability, security, scalability, and interoperability must be taken into account from the outset.

VII. CONCLUSIONS

This article demonstrates that information exchange is a fundamental prerequisite for the effective management of automated warehouse transport. The IIoT concept makes it possible to integrate mobile transport vehicles, sensors, embedded controllers, dispatch servers, WMS, and operator interfaces into a single information system. The key principles of such interaction are hierarchy, real-time operation, standardized data exchange, reliability, scalability, and security.

The practical significance of the approach discussed lies in the fact that it provides a theoretical foundation for further research into models and methods for controlling automated vehicles in warehouse systems. In the future, it would be advisable to focus on developing models for coordinating AGV/AMR fleets, mechanisms for adaptive route replanning, and methods for aligning local vehicle decisions with the global objectives of the warehouse system.

REFERENCES

[1] European Commission. (2024). Industry 5.0. Retrieved June 16, 2026, from https://research-and-innovation.ec.europa.eu/research-area/industrial-research-and-innovation/industry-50_en

[2] Keith, R., & La, H. M. (2024). Review of Autonomous Mobile Robots for the Warehouse Environment. arXiv. https://arxiv.org/abs/2406.08333

[3] Industry IoT Consortium. (2022). The Industrial Internet Reference Architecture v1.9. https://www.iiconsortium.org/IIRA.htm

[4] OPC Foundation. (2026). Unified Architecture – Landing Page. https://opcfoundation.org/about/opc-technologies/opc-ua/

[5] 5G Alliance for Connected Industries and Automation. (2026). Integration of 5G with Time-Sensitive Networking for Industrial Communications. https://5g-acia.org/whitepapers/integration-of-5g-with-time-sensitive-networking-for-industrial-communications/

[6] Boyes, H., Hallaq, B., Cunningham, J., & Watson, T. (2018). The industrial internet of things (IIoT): An analysis framework. Computers in Industry, 101, 1–12

[7] Brauner, P., Dalibor, M., Jarke, M., Kunze, I., & Koren, I. (2022). A computer science perspective on digital transformation in production. ACM Transactions on Internet of Things, 3(1), Article 2