UDC 004.9 **doi: 10.26906/SUNZ.2024.3.113**

Sergii Datsenko[1], Denys Tarasenko[2]

[1] National Technical University "Kharkiv Polytechnic Institute", Kharkiv, Ukraine
[2] Cherkasy State Technological University, Cherkasy, Ukraine

RESEARCH OF INDUSTRIAL INTERNET OF THINGS NETWORKS AND SYSTEMS

Abstract. The article discusses the concept of the Industrial Internet of Things. The main protocols for data transmission of the Industrial Internet of Things were identified. IIoT systems have high requirements for the reliability of message delivery, which is why special industry data transmission protocols used in industrial automation are often used to develop IIoT systems. IIoT technologies are an integral part of the Internet of Things concept. The paper presents the architecture of an automated enterprise based on IIoT, highlighting its advantages and disadvantages.

Keywords: IoT IIoT, automation, integration.

Introduction

Currently, the concept of the Internet of Things is actively developing, which implies the active implementation of embedded technologies in modern infocommunication networks [1–4]. This concept covers an increasing number of areas of human activity every day, such as unmanned transport control, urban infrastructure management, control of medical operations, automation of residential premises, offices, etc. [5–8]. Recently, a new direction has been developing within the concept of the Internet of Things (IoT) - the industrial Internet of Things (IIoT), which affects the issues of creating a heterogeneous intelligent system for automating industrial enterprises. IIoT systems are used in a variety of production areas, such as agriculture, electronic equipment manufacturing, mechanical engineering, machine tool manufacturing, automation of data collection and accounting from energy networks, production of aviation, space and military equipment, etc. Currently, the implementation of technologies related to the industrial Internet of Things is associated with problems both with the integration of these technologies with outdated solutions for industrial automation, and with the absence of any automation system at the enterprise [9–14]. The solution to these problems lies in the development of unified technological standards for the integration of both industrial automation systems and equipment that does not have digital control interfaces with IIoT systems [15, 16].

Basic material

There are a number of areas in industrial enterprises whose work is subject to automation. In addition to the obvious automation of production equipment, there are a number of areas subject to automation within the enterprise and related to human safety and social activities. The following areas should be highlighted as the main areas of automation [17]:

– automation of production equipment;

– automation of monitoring and management of the state of the enterprise's products;

– automation of business applications, such as enterprise resource planning (ERP), customer relationship management (CRM), product lifecycle management (PLM), manufacturing execution systems (MES), human resource management (HRM), etc.;

– automation of multimedia systems for monitoring industrial enterprise safety;

– automation of local and global positioning systems;

– automation of collection and analysis of openly accessible data from the Internet.

IIoT technologies are an integral part of the Internet of Things concept. Fig. 1 shows an architecture that consists of four functional and two non-functional layers.

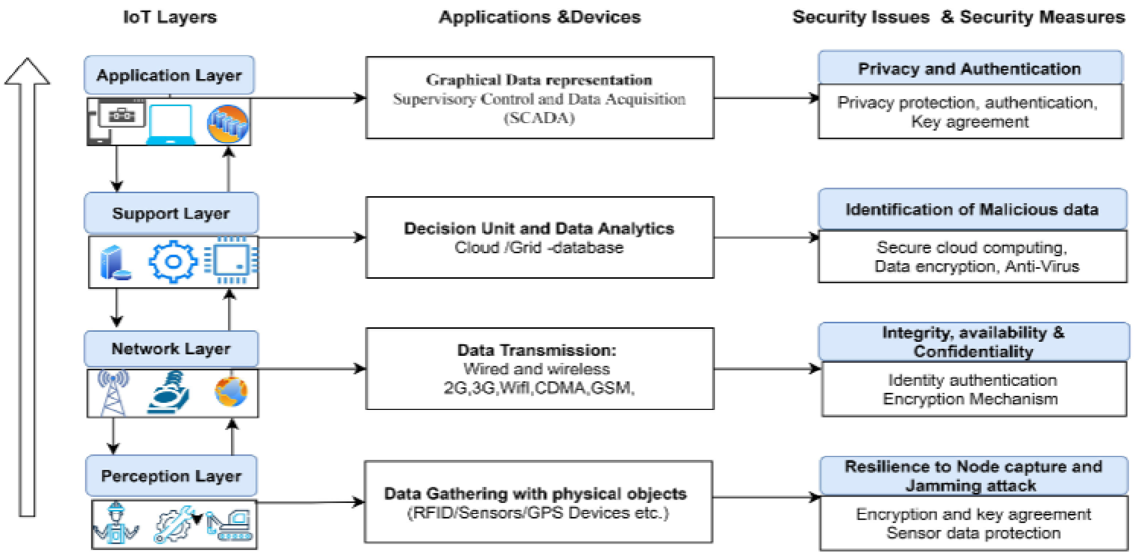

Fig. 1. IIoT layered architecture

The functional layers include the following [18]:

1. Application layer.
2. Service support and application support layer.
3. Network layer.
4. Device layer.

Fig. 2 shows the functional architecture of smart manufacturing systems based on Industrial Internet of Things solutions.

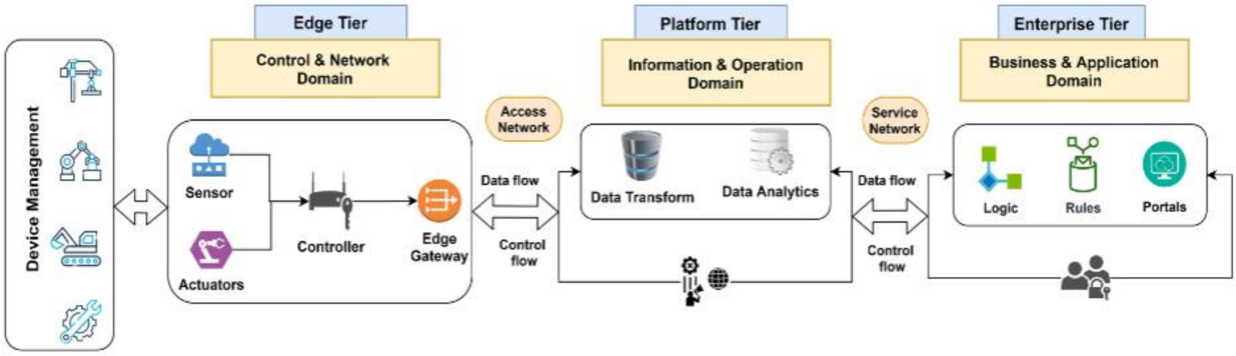

Fig. 2. Three T IIoT System architecture

It is divided into the following levels [19]:

1. ***Life Cycle Management Level***. This level is responsible for managing the various life cycles of the manufacturing enterprise and covers a wide range of systems in the manufacturing enterprise, such as systems for design, production, management and maintenance of manufactured products.

The following can be distinguished as the main life cycles of an enterprise:

– The product cycle, which includes the design and development of the corresponding production system, design, development, production, testing, maintenance of the manufactured product, use of the product by the user, recycling or destruction of the used product.

– The production system cycle, which includes the design, assembly, operation, maintenance and decommissioning of the entire production system.

– The implementation cycle, which includes functions related to the interaction of the supplier and the customer.

Other life cycles that can also be included in the system under consideration, if there are special requirements for a “smart enterprise”.

2. ***The integration level***, which ensures the integration of all resources, systems and processes involved in the various life cycles associated with the creation of products, through all levels of the production system to create an environment for smart manufacturing applications. This level includes the following types of integration:

– Vertical integration, which is responsible for ensuring that new technological solutions are included in an existing system through higher levels of the production system.

– Horizontal integration, which is responsible for ensuring that new technological solutions are integrated into an existing system at one system level.

– End-to-end integration, which allows connecting each phase of the life cycle of the manufactured product through the entire chain of product implementation, including through various enterprises.

3. ***The application layer***, which is responsible for implementing end applications used to solve various problems that arise in smart manufacturing. Examples include the following applications:

– Innovative manufacturing is a type of “smart manufacturing” and includes applications such as virtual manufacturing, flexible manufacturing, and customized manufacturing. Virtual manufacturing allows for the simulation of production processes at the enterprise and computer modeling. Flexible manufacturing allows for a quick response to predictable and unpredictable changes. Customized manufacturing allows for the sale of goods in a way that meets the needs of each individual customer.

– Preventive maintenance is responsible for analyzing data coming from production tools equipped with various types of sensors that collect information about the current state of the equipment, and making decisions based on the analysis results, which can potentially lead to the prevention of equipment failures.

To highlight the task that will be revealed in this paper, we will highlight the main data transfer protocols of the Industrial Internet of Things. IIoT systems have high requirements for the reliability of message delivery, as a result of which IIoT system developers very often use special industry data transfer protocols used in the field of industrial automation. The following technologies were selected for the study of IIoT data transfer protocols:CoAP (Constrained Application Protocol)

– MQTT (Message Queuing Telemetry Transport);

– XMPP (Controller Area Network);

– HTTP (HyperText Transfer Protocol);

– ModBus;

– OPC UA (Open Platform Communications Unified Architecture).

Currently, there is an active development and implementation of such a class of devices in the networks of the Internet of Things and the Industrial Internet of Things, such as gateways. These devices are responsible for ensuring the interaction of specific communication technologies and data transfer of IoT and IIoT, both among themselves and with public communication networks.

Conclusions

The article discusses the concept of the Industrial Internet of Things. The main protocols for data transmission of the Industrial Internet of Things were identified. IIoT systems have high requirements for the reliability of message delivery, which is why special industry data transmission protocols used in industrial automation are often used to develop IIoT systems. IIoT technologies are an integral part of the Internet of Things concept.

The article presented the architecture of an automated enterprise based on IIoT, highlighting its advantages and disadvantages.

REFERENCES

1. Rafique, H., Shah, M. A., Islam, S. U., Maqsood, T., Khan, S. and Maple, C. (2019), "A novel Bio-Inspired Hybrid Algorithm (NBIHA) for efficient resource management in Fog computing", *IEEE Access*, vol. 7, pp. 115.760–115.773, doi: https://doi.org/10.1109/access.2019.2924958
2. Wang, T., Zhou, J., Chen, X., Wang, G., Liu, A. and Liu, Y. (2018), "A Three-Layer privacy preserving cloud storage scheme based on computational intelligence in FOG computing", *IEEE Transactions on Emerging Topics in Computational Intelligence*, vol. 2(1), pp. 3–12, doi: https://doi.org/10.1109/tetci.2017.2764109
3. Petrovska, I. and Kuchuk, H. (2023), "Adaptive resource allocation method for data processing and security in cloud environment", *Advanced Information Systems*, vol. 7, is. 3, pp. 67–73, doi: https://doi.org/10.20998/2522-9052.2023.3.10
4. Dang, L. M., Piran, M. J., Han, D., Min, K. and Moon, H. (2019), "A survey on internet of things and cloud computing for healthcare", *Electronics*, vol. 8(7), 768, doi: https://doi.org/10.3390/electronics8070768
5. Botta, A., De Donato, W., Persico, V. and Pescapè, A. (2016), "Integration of Cloud computing and Internet of Things: A survey", *Future Generation Computer Systems*, vol. 56, pp. 684–700, doi: https://doi.org/10.1016/j.future.2015.09.021
6. Díáz, M., Martin, C. L. and Rubio, B. (2016), "State-of-the-art, challenges, and open issues in the integration of Internet of things and cloud computing", *Journal of Network and Computer Applications*, vol. 67, pp. 99–117, doi: https://doi.org/10.1016/j.jnca.2016.01.010
7. Liu, Y., Fieldsend, J. E. and Min, G. (2017), "A framework of FOG Computing: architecture, challenges, and optimization", *IEEE Access*, vol. 5, pp. 254.45–254.54, doi: https://doi.org/10.1109/access.2017.2766923
8. Kuchuk, N., Mozhaiev, O., Haichenko, A., Semenov, S., Kuchuk, H., Tiulieniev, S., Mozhaiev, M., Davydov, V., Brusakova, O. and Gnusov, Y. (2023), "Devising a method for balancing the load on a territorially distributed foggy environment", *Eastern-European Journal of Enterprise Technologies*, vol. 1(4 (121)), pp. 48–55, doi: https://doi.org/10.15587/1729-4061.2023.274177
9. Chiang, M. and Zhang, T. (2016), "Fog and IoT: An Overview of Research Opportunities", *IEEE Internet of Things Journal*, vol. 3(6), pp. 854–864, doi: https://doi.org/10.1109/jiot.2016.2584538
10. Puliafito, C., Mingozzi, E. and Anastasi, G. (2017), "Fog Computing for the Internet of Mobile Things: Issues and Challenges", *2017 IEEE Int. Conf. Smart Comput*, doi: https://doi.org/10.1109/smartcomp.2017.7947010
11. Khan, S., Parkinson, S. and Qin, Y. (2017), "Fog computing security: a review of current applications and security solutions*",* *Journal of Cloud Computing*, vol. 6(1), doi: https://doi.org/10.1186/s13677-017-0090-3
12. Hamdan, S., Ayyash, M. and Almajali, S. (2020), "Edge-Computing Architectures for Internet of Things Applications: A survey", *Sensors*, vol. 20(22), 6441, doi: https://doi.org/10.3390/s20226441
13. Li, Y., Qi, F., Wang, Z., Yu, X. and Shao, S. (2020), "Distributed edge Computing offloading algorithm based on deep reinforcement learning", *IEEE Access*, vol. 8, pp. 85.204–85.215, doi: https://doi.org/10.1109/access.2020.2991773
14. Premsankar, G., Di Francesco, M. and Taleb, T. (2018), "Edge Computing for the Internet of Things: a case study", *IEEE Internet of Things Journal*, vol/ 5(2), pp. 1275–1284, doi: https://doi.org/10.1109/jiot.2018.2805263
15. Xue, H., Huang, B., Qin, M., Zou, H. and Yang, H. (2020), "Edge Computing for Internet of Things: A Survey", *2020 Int. Conf. Internet Things IEEE Green Comput. Commun. IEEE Cyber*, Phys. Soc. Comput. IEEE Smart Data IEEE Congr. Cybermatics, IEEE, doi: https://doi.org/10.1109/ithings-greencom-cpscom-smartdata-cybermatics50389.2020.00130
16. Liu, J., Mao, Y., Zhang, J. and Letaief, K. B. (2016), "Delay-optimal computation task scheduling for mobile-edge computing systems", *2016 IEEE Int. Symp. Inf. Theory*, IEEE, doi: https://doi.org/10.1109/isit.2016.7541539
17. Kuchuk, N., Ruban, I., Zakovorotnyi, O., Kovalenko, A., Shyshatskyi, A. and Sheviakov, I. (2023), "Traffic Modeling for the Industrial Internet of NanoThings", *2023 IEEE 4th KhPI Week on Advanced Technology*, KhPI Week 2023 - Conference Proceedings, 194480, doi: https://doi.org/10.1109/khpiweek61412.2023.10312856
18. Παπαγεωργιου, A., Poormohammady, E. and Cheng, B. (2016), "Edge-Computing-Aware Deployment of Stream Processing Tasks Based on Topology-External Information: Model, Algorithms, and a Storm-Based Prototype", *2016 IEEE Int. Congr. Big Data*, doi: https://doi.org/10.1109/bigdatacongress.2016.40
19. Zhou, J., Leppänen, T., Harjula, E., Ylianttila, M., Ojala, T., Chen, Y., Jin, H. and Yang, L. T. (2013), "CloudThings: A common architecture for integrating the Internet of Things with Cloud Computing", *2013 IEEE 17th Int. Conf. CSCWD 2013*, doi: https://doi.org/10.1109/cscwd.2013.6581037

Received (Надійшла) 12.05.2024
Accepted for publication (Прийнята до друку) 14.07.2024

Дослідження мереж і систем промислового Інтернету Речей

С. С. Даценко, Д. А. Тарасенко

Анотація. У статті розглянуто концепцію промислового Інтернету речей. Було виділено основні протоколи передачі даних промислового Інтернету речей. Системи IIoT мають високі вимоги до показників надійності доставки повідомлень, внаслідок чого часто-густо для розробки систем IIoT використовують спеціальні галузеві протоколи передачі даних, що використовуються у сфері промислової автоматизації. Технології IIoT є складовою концепції Інтернету речей. У роботі представлено архітектуру автоматизованого підприємства на основі IIoT, виділено її переваги та недоліки.

Ключові слова: IoT, IIoT, автоматизація, інтеграція.