Applications of IoT in production logistics: Opportunities and challenges

Q. Yu & K. Wang
Department of Production and Quality Engineering, Norwegian University of Science and Technology, Norway

Abstract

Companies and researchers have been pursuing Internet of Things (IoT) for decades. With the rapid development of radio frequency identification (RFID) and cloud computing technologies, IoT has increasingly become technically feasible in many industries. As the earliest industry field related to IoT, production logistics will benefit from this innovative technology by improving the ability of tracing and tracking, responsiveness, resource management, decision support, etc. Meanwhile, challenges still exist in the implementation of IoT, e.g. integration of systems, information security, Big Data analysis, and decision-making methods. In this paper, a brief introduction of the development of research on IoT in production logistics is provided as a reference for further research work.
Keywords: Internet of Things, radio frequency identification, production logistics.

1 Introduction

Internet of Things (IoT) was envisaged as a network of objects and sensors that collect and process information autonomously to enable computers to observe, identify, and gain situational awareness. The term IoT was linked to radio frequency identification (RFID) and supply chain management. After decades, the evolution of IoT has brought increasing opportunities and challenges in production logistics.

The collection, comprehension, and utilization of business data will affect the competitiveness of a company. Internet of Things solutions provide more connections among various systems and sensors via the broader Internet. Assets are digitally identified and automatically tracked with embedded technologies such as RFID.

doi:10.2495/IWAMA150271

The rapid development of RFID technology sharply reduced the cost of identifying assets and has also made remote and unattended asset management possible. Combining with other sensors, RFID not only enhances the identification of monitored items, but also provides another way to identify the sensors themselves [1, 2]. However, there is not a single generally accepted IoT solution at present.

Production logistics encompasses logistic processes, which include all activities related to the supply of products with feedstock such as raw materials and work in progress (WIP), and the delivery of semifinished and finished products to the distribution center. Production logistics connects procurement logistics and distribution logistics. Thereby, the fundamental goal of production logistics can be formulated as the pursuance of greater delivery capability and reliability at the lowest possible logistic and production costs [3]. However, in different logistic processes, the objectives are often competing (Table 1).

Table 1: Objectives in different production processes [3].

Production processes / Logistic objectives	Production and testing	Transport	Storage and supply
Schedule adherence	High schedule reliability	High schedule reliability	Low delivery delay
Throughput time	Short throughput time	Short transport throughput time	Short storage time
Output rate	High utilization	High utilization	
Inventory	Low WIP	Low WIP	Low stock
Costs	Low costs per unit	Low costs per transport operation	Low storage costs

Since production logistics increasingly requires responsiveness, IoT techniques can contribute by facilitating real-time feedstock data collection, promoting a more collaborative software environment, and enhancing global and local decision-support capabilities.

2 Capability of IoT technologies

Compared with traditional machine-to-machine (M2M) technologies, IoT concerns more general Internet technologies. Communication among sensors, actuators, and systems follows various network protocols, according to specific working conditions.

IoT technologies enhance data-acquisition capability. In a production process, raw data is collected, which is not meaningful until it is converted to information and, finally, knowledge for decision support. Information is defined as the enrichment of data with the right context, while data is perceived as raw values without relevant or usable context [4]. The utilization of data comprises data visualization and data mining. The former focuses on the representation of data, combining with infrastructures or hardware systems (such as an item-tracking system) for monitoring or tracking assets, etc. [5, 6]. The latter focuses on the data mining process according to raw data and relevant context, which generates high-level information and even knowledge for decision support based on Big Data analytics [7]. Generally, an IoT solution for production logistics is a cyber-physical system (CPS) (Fig. 1). On the basis of specific utilization, physical facilities directly related to production can be divided into three categories: manufacturing, transportation, and storage facilities. Manufacturing facilities include mainly machines and robots used for processing feedstock. Transportation facilities refer to equipment that ship feedstock, such as pallets, conveyer belts, forklifts, automated guided vehicles, and robots. Storage facilities are designed for stocking feedstock and finished goods as a buffer in a warehouse.

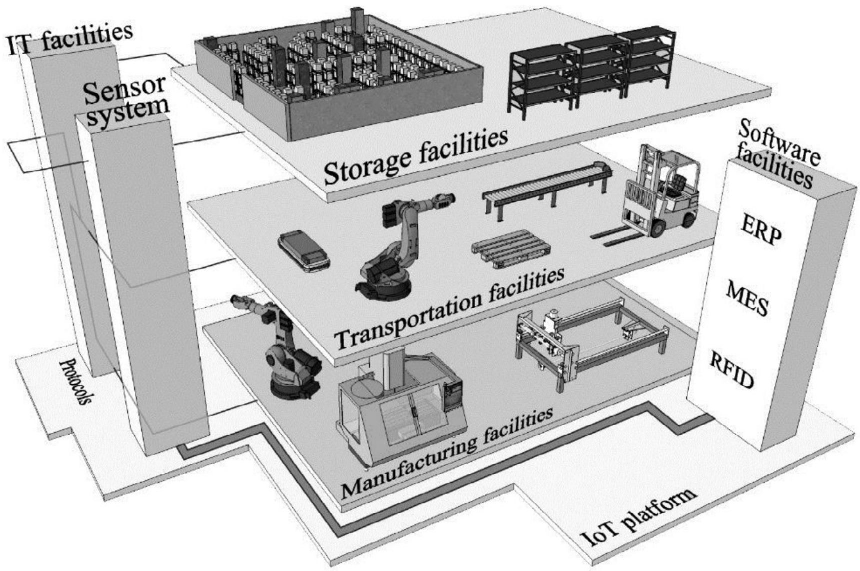

Figure 1: An IoT platform for production logistics.

Furthermore, in the IoT platform, IT and software facilities constitute the cyber-environment of physical equipment. Databases of feedstock, finished goods, and equipment are built and maintained by the cyber-system. Thereby, the production progress can be monitored and managed via specific software.

Meanwhile, the sensor system provides a vital link between the physical world and cyber-environment and promotes a seamless CPS. Sensors that are traditionally used for measurements are enhanced by combining with other techniques such as wireless communication, which also improve their performance. Additionally, the utilized identifying technologies rapidly develop from barcode and Quick Response (QR) code to RFID. The increasing application of RFID will definitely stimulate its upgrade and promote an ever more integrated CPS.

3 Opportunities of IoT in production logistics

IoT can provide production logistics with a CPS enabled by Internet-based information communication technologies. Since the main advantage of IoT over M2M is the utilization of Internet techniques, the biggest contribution of IoT in production logistics will occur in the field where more connections can be built among hardware. Especially, RFID techniques can enable the tagging and automatic identification of each equipment, device and even item [2], which constructs the IT infrastructure of an IoT system available for tracking and tracing [6, 8].

Opportunities for IoT in production logistics can be divided into the following: constructing a seamlessly integrated environment, enhancing the scalability, configurability, and extendibility of the production system, facilitating autonomous agent-based local collaboration, and promoting quick rescheduling and planning in production logistics.

3.1 Constructing a seamlessly integrated environment

The first contribution of IoT technologies is automated item registration. Historically, automated identification and registration of items in the production logistic system have relied on barcode or QR code, which needs human operators or vision systems to scan the code and retrieve the identity of an item. Thereby, the registration time of items in the production logistic system is a bottleneck in improving efficiency. An IoT system uses an RFID system as an alternative method for the registration of items in high-level management software systems such as an ERP system [9]. Without artificial interference, it is capable of achieving real-time item registration in the production logistic management system, e.g. working stations can be identified and items produced can be recorded automatically [6, 10–13].

3.2 Facilitating an autonomous agent-based local collaboration

On the basis of automated registration, an IoT system also provides the possibility of smart agent. Specifically, equipment shipped can be monitored and located in management systems [8, 14]. Furthermore, equipment can communicate with each other by following specific network protocols [15–17]. A distributed self-organized “community” of shipping equipment can be formed based on swarm intelligence activities.

3.3 Promoting quick rescheduling and planning in production logistics

Owing to improved communication capability and enhanced data collection in terms of both quantity and quality, the production logistic management system will have more real-time data available for making production and logistic plans. Since decision support is vital for production logistics, this real-time data is of great value to make data-driven decisions for scheduling [18, 19] and resource allocation [20–22].

4 Challenges of IoT in production logistics

With the sharp increase in interest on IoT, researchers are keeping an eye on the challenges faced by IoT in applications, which originate from techniques, standards, security, research methodologies, etc. Considering RFID techniques as examples, the cost of one RFID tag is about a few cents, which is still more expensive than printable bar code tags. Meanwhile, an RFID system needs readers and antennas as tag-interrogating devices, which will be a high initial investment for companies. Thus, a hybrid system mixing bar code technologies and RFID technologies is the most common solution currently.

Another challenge comes from standards of IoT, or in other words, a widely accepted standard for an IoT solution is not available as yet. Although standards (EPCIS, ALE, etc.) for RFID technologies are available, which are mainly designed for logistics and supply chain, additional efforts in the process of software system integration are necessary. This problem affects the extendibility of an IoT system.

System security is another challenge for IoT applications. An IoT system is Internet based, while databases and decision-support systems are generally based on remote "clouds." Thus, collected data and communication systems must be protected from unauthorized access.

Decision-support systems, i.e. the processing of massive IoT data, pose the biggest challenge. An IoT system can produce much more data than an M2M system. However, it is nontrivial to make the data comprehensible and achieve decision support. Missing values are very common in practical systems, and will be more prevalent in IoT systems. Moreover, in a large-scale network, network latency can lead to asynchronous data, which should be avoided. Therefore, a missing-value-processing policy and a synchronization mechanism are often required [23].

Since an IoT solution generally comprises multiple domains, relationships between data have to be studied; ontology study can be considered a feasible method to study such relationships. Ontology study has been developed in supply chain management [24]. The concept of semantic web has been proposed by the World Wide Web Consortium for sharing data and reusing across applications, enterprises, and communities [25]. Ontology research has already become another popular topic for IoT data analysis [26–29].

5 Conclusions

IoT is being increasingly accepted by companies in production logistics and other fields. Pioneers are implementing current IoT solutions in business while others are following up. The benefits of management, optimization, and responsiveness derived from IoT solutions are tremendous, while the challenges of security, tolerance, and efficient decision support cannot be ignored, areas where further research work will be carried out.

References

[1] Chen, Y.-Y., Y.-J. Wang, and J.-K. Jan, A novel deployment of smart cold chain system using 2G-RFID-Sys. *Journal of Food Engineering,* **141**, pp. 113–121, 2014.

[2] Briand, D., F. Molina-Lopez, A.V. Quintero, G. Mattana, and N.F. De Rooij, Printed sensors on smart RFID labels for logistics. *2012 IEEE 10th International New Circuits and Systems Conference, NEWCAS 2012*, Montreal, QC, pp. 449–452, 2012.

[3] Nyhuis, P., and H.-P. Wiendahl, *Fundamentals of production logistics: Theory, tools and applications*, Springer, Berlin, 2009.

[4] Rowley, J., The wisdom hierarchy: Representations of the DIKW hierarchy. *Journal of Information Science*, **33(2)**, pp. 163–180, 2007.

[5] Ilic, A., T. Andersen, and F. Michahelles, Increasing supply-chain visibility with rule-based RFID data analysis. *IEEE Internet Computing,* **13(1)**, pp. 31–38, 2009.

[6] Kvarnström, B., and E. Vanhatalo, Using RFID to improve traceability in process industry: Experiments in a distribution chain for iron ore pellets. *Journal of Manufacturing Technology Management,* **21(1)**, pp. 139–154, 2010.

[7] Ho, G.T.S., K.L. Choy, and T.C. Poon, Providing decision support functionality in warehouse management using the RFID-based fuzzy association rule mining approach. *8th International Conference on Supply Chain Management and Information Systems (SCMIS),* Hong Kong, pp. 1–7, 2010.

[8] Kirsch, F., R. Miesen, and M. Vossiek, Precise local-positioning for autonomous situation awareness in the Internet of Things. *2014 IEEE MTT-S International Microwave Symposium, IMS 2014*, Institute of Electrical and Electronics Engineers Inc., Tampa, FL, 2014.

[9] Prasse, C., A. Nettstraeter, and M.T. Hompel, How IoT will change the design and operation of logistics systems. *2014 International Conference on the Internet of Things, IOT 2014*, Institute of Electrical and Electronics Engineers Inc., Tampa, FL, pp. 55–60, 2014.

[10] Libert, S., A. Nettsträter, and M. Ten Hompel, Methods for analysis of the time aspect in the behavior of agent-based material flow controls. *21st European Modeling and Simulation Symposium, EMSS 2009*, Puerto de la Cruz, 2009.

[11] Wang, Z.-g., R.-z. Tang, W.-l. Sheng, and G.-d. Wang, Research on RFID-based production logistics management techniques with application in garment industry. *Technology and Innovation Conference, 2006. ITIC 2006. International*, Hangzhou, China, pp. 383–387, 2006.

[12] Xu, Z., J. He, and Z. Chen, Design and actualization of IoT-based intelligent logistics system. *2012 IEEE International Conference on Industrial Engineering and Engineering Management, IEEM 2012*, IEEE Computer Society, Hong Kong, pp. 2245–2248, 2012.

[13] Liu, M., J. Ma, L. Lin, M. Ge, Q. Wang, and C. Liu, Intelligent assembly system for mechanical products and key technology based on internet of things. *Journal of Intelligent Manufacturing*, pp. 1–29, 2014.

[14] Mättig, B., M. Fiedler, A. Hille, and B. Anderseck, How AutoID processes shape the internet of things: The OpenID-center development process. *1st International Conference on The Impact of Virtual, Remote, and Real Logistics Labs, ImViReLL 2012*, Bremen, pp. 134–147, 2012.

[15] Stasch, A., and A. Hahn, Towards a multi-agent platform for cyber-physical systems based on low-power microcontroller for automated intralogistics: A minimized embedded solution for the internet of things in intralogistical environments. *10th International Conference on Informatics in Control, Automation and Robotics, ICINCO 2013*, Reykjavik, pp. 429–433, 2013.

[16] Chiti, F., and R. Fantacci, Intelligent and cooperative environments via internet of sensors: Perspectives and case study analysis. *9th International Wireless Communications and Mobile Computing Conference, IWCMC 2013*, Cagliari, Sardinia, pp. 19–23, 2013.

[17] Rico, J., B. Cendón, J. Lanza, and J. Valiño, Bringing IoT to hospital logistics systems: Demonstrating the concept. *2012 IEEE Wireless Communications and Networking Conference Workshops, WCNCW 2012*, Paris, pp. 196–201, 2012.

[18] Hu, M., H. Hou, H. Zhu, and Y. Geng, Basic theories and enabling technologies of intelligent logistics. *2012 International Conference of Logistics Engineering and Management: Logistics for Sustained Economic Development – Technology and Management for Efficiency, ICLEM 2012*, Chengdu, pp. 390–396, 2012.

[19] Zhang, Y., G.Q. Huang, S. Sun, and T. Yang, Multi-agent based real-time production scheduling method for radio frequency identification enabled ubiquitous shopfloor environment. *Computers & Industrial Engineering,* **76**, pp. 89–97, 2014.

[20] Lee, C.K.H., K.L. Choy, G.T.S. Ho, and K.M.Y. Law, A RFID-based resource allocation system for garment manufacturing. *Expert Systems with Applications,* **40(2)**, pp. 784–799, 2013.

[21] Zhong, R.Y., G.Q. Huang, S. Lan, Q.Y. Dai, T. Zhang, and C. Xu, A two-level advanced production planning and scheduling model for RFID-enabled ubiquitous manufacturing. *Advanced Engineering Informatics,* In Press, Corrected Proof, available online 31 January 2015.

[22] Huang, G., Y.F. Zhang, X. Chen, and S. Newman, RFID-enabled real-time wireless manufacturing for adaptive assembly planning and control. *Journal of Intelligent Manufacturing,* **19(6)**, pp. 701–713, 2008.

[23] Yan, X., W. Xiong, L. Hu, F. Wang, and K. Zhao, Missing value imputation based on Gaussian mixture model for the internet of things. *Mathematical Problems in Engineering,* **2015**, 2015, available online.
[24] Geerts, G.L., and D.E. O'Leary, A supply chain of things: The EAGLET ontology for highly visible supply chains. *Decision Support Systems,* **63**, pp. 3–22, 2014.
[25] Archer, P., W3C DATA ACTIVITY, Building the Web of Data, 2013.
[26] Schief, M., C. Kuhn, P. Rösch, and T. Stoitsev, Enabling business process integration of IOT-events to the benefit of sustainable logistics. *1st International Conference on Logistics, Informatics and Service Science, LISS 2011*, Beijing, pp. 40–49, 2011.
[27] Kiritsis, D., Closed-loop PLM for intelligent products in the era of the Internet of Things. *Computer-Aided Design,* **43(5)**, pp. 479–501, 2011.
[28] Wang, X., and Y. Yu, Semantic-driven model of dynamic logistic services composition and optimization based on QoS. *Bio-Inspired Computing: Theories and Applications (BIC-TA)*, Changsha, pp. 918–922, 2010.
[29] Qu, C., F. Liu, and M. Tao, Ontologies for the transactions on IoT. *International Journal of Distributed Sensor Networks,* **29,** 2015.