Logistics 4.0 Solution

New Challenges and Opportunities

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***Abstract*—Logistics 4.0 will change and improve traditional logistics and its self-perception. Logistics has become a core pillar in the value chain for industries and it is crucial for them to have the right good with the right quantity and right quality at the right time at the right place and in the right condition and at right price (7R), otherwise they cannot be competitive in the market. In a dynamically changing and uncertain logistic environment, fulfilling these requirements is getting more and more difficult. The highly dynamic and uncertain logistic markets and huge logistic networks require new methods, products and services. Today's consumer behavior leads to new logistics challenges and opportunities. The concept of the cyber physical system (CPS), the wireless networks, the Internet of Things and Services (IOT&S), Big Data/Data Mining (DM) and cloud computing, etc. seem to be the probable technical solution for that. Its consequent implementation inevitably results in the necessity to reconsider some basic concepts of traditional logistics. This paper is to outline the vision of "Logistics 4.0" and give a definition and propos some basic technical components of logistic 4.0. Additionally it emphasizes the question, which paradigm changes will emerge from the fourth industrial revolution and how to address them proactively. Two laboratory cases show how to implement the technologies in logistics 4.0.**

Keywords—Logistics 4.0; Industry 4.0; CPS; IOT&S; big data/ data mining; manufacturing; supply chain

I. INTRODUCTION

Industry is the part of the economy that carries out the production of materials and goods, which are highly mechanized and automatized. From the beginning of the industrialization, technological changes have driven the paradigm shifts that are called "Industrial Revolutions" [1] Nowadays, the industrial production has reached the edge of a new industrial revolution and the factory of the future has been pictured. The new industry revolution can be named "Industry 4.0". [2] [3]

Industry 4.0 will change and improve traditional logistics and its self-perception. Logistics has become a core pillar in the value chain for suppliers, manufacturers and retailers. It is crucial for them to have the Right good with the Right quantity and Right quality at the Right time at the Right place and in the Right condition and at Right price (7R), – these are the well-known requirements for logistics, and otherwise they cannot be competitive in the market. [4]

In a dynamically changing and uncertain logistic environment, fulfilling these requirements is getting more and more difficult. The highly dynamic and uncertain logistic markets and huge complex logistic networks require new methods, products and services. Today's consumer behavior leads to new logistics challenges and opportunities. There is a shift from traditional supply chains to open supply network.

Aspects such as flexibility, adaptability, proactivity and self-organization gain importance and can only be achieved by integration of new intelligent technologies. While problem initiated approaches usually only lead to minor improvements, technology driven approaches can evoke changes that are major and even more radical.

The fourth industrial revolution has already begun, along with the transformation of existing value chains and networks. Extensive connectedness now allows machines, warehousing systems, logistics equipment and products to exchange information, prompting autonomous actions and enabling them to control one another's activities. The central promise of the Industrial Internet is complete transparency from supplier to customer, networked processes, and decentralized management, in addition to cost-effective small batch manufacturing and high numbers of variants. These goals can only be achieved with a digital supply chain shaped by Logistics 4.0. [5, 6, 7, 8]

The essential characteristic of Logistics 4.0 – is its implementation across organizations and processes. The market currently offers just a variety of individual technical solutions such as transportation management systems, interconnected containers or driverless transportation systems. These own elements form merely parts of the digital supply chain. We need to make them contributors to a larger overall concept of complete connection along the entire supply chain. [9, 10, 11]

A report [12] shows that potential cost savings of 20 percent in supply chain, quality, and maintenance, each, and more than 30 percent in inventory costs are made possible for implementing logistics 4.0 in a supply chain.

Even if Logistics 4.0 is a buzzword, but what it is, what is the framework of it and how it can be implemented in practice are still not clear for most of industries. This paper outlines the vision of "Logistics 4.0" and emphasizes the question, which paradigm changes will emerge from the fourth industrial revolution and how to address them proactively. Two cases on logistics 4.0 show how smart sensor devices monitor goods and data mining help the decision of the real time location of goods across the supply chain. The increase in transparency and accurate position results in a reduction of transport damages and an improvement in quality.

II. Logistics 4.0

A. Evolotion processes of logistics

Logistics has undergone three of revolutionary changes in the past. The first innovation (Logistics 1.0) is caused by "mechanization of transport" from the late 19th century and early 20th century. The second innovation (Logistics 2.0) is driven by "automation of handling system" from the 1960s. The third innovation (Logistics 3.0) is represented by "the system of logistics management" from the 1980s. Now we are in the beginning of the fourth innovation of logistics, which is called Logistics 4.0. The main driven force is IOT&S (Internet of Thing and Service). Fig. 1 presents the evolutionary process of Logistics over the time.

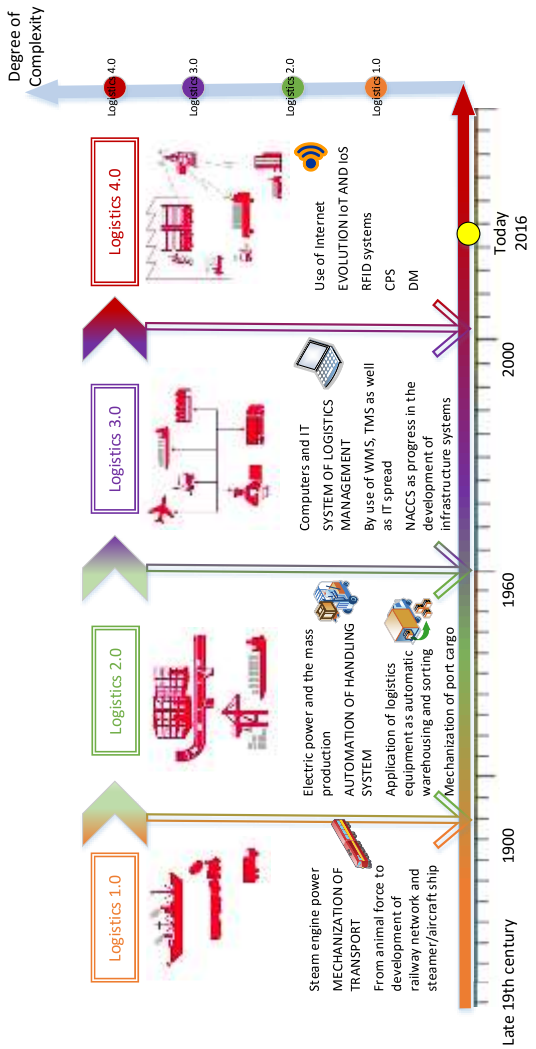

Fig. 1. .Evolution process of Logistics

1) Logistics 1.0

The first innovation is the mechanization of transportation from the late 19th century and early 20th century. Ships and trains equipped with steam engines had been used as a main transportation tools instead of humans and animal power for transporting goods and containers in large qualities and long distance. Transportation capacity has been enhanced significantly. Logistics in 20 century can be said that it was the beginning of the mass transportation era.

2) Logistics 2.0

The invention of electric power and mass production in manufacturing lead to the second innovation of logistics, which is named by the automation of cargo handling. Due to the practical application of logistic equipment, such as automatic warehouses and automatic sorting systems, automatic loading/unloading system, machines driven by electrical motors can do most heavy work in logistics. The container ships are widely used in port and they change the port cargo handling system.

3) Logistics 3.0

The third innovation is the systemization of logistics management and it starts from the 1980s due to the invention of computers and IT technology. By the use of IT system in logistics, such as WMS (Warehouse Management System) and TMS (Transport Management System), automation and efficiency of logistics management, inventory and dispatch has been significantly progressed and improved.

The fourth of innovation is progressing presently, namely Logistics 4.0, which is driven mainly by IoT&S and big data. The main purpose of Logistics 4.0 is for labor saving and standardization in supply chain management.

B. Logistics 4.0 in supply chain

Evolution of IoT&S and big data will greatly reduce the work that requires humans intervention in each step of the supply chain. New technologies such as automatic guide vehicle (AGV) and warehouse robot is replacing the process which is operated and decision-making by the humans. The Fig. 2 is a summary of the future activities in supply chain within the concept of Logistics 4.0.

The supply chain management will be a big network where all the stakeholders in the supply chain (form suppliers to customers) are able to access it. An internet platform is used and all the orders from the customers/suppliers can be managed in real time/online.

The intralogistics or the movement of goods inside the factory are completely automated with autonomous forklifts, AGVs and robots with a routed program that is based on the predictive inbound logistics. All activities in logistcs will come from the information received from the internet platform used by all the stakeholders.

The warehouses expense can be reduced to the minimum or might disappear completely because the customers' orders and the orders to the suppliers are processed at the same time

Fleet vehicles will have a routed program by the use of the internet platform from where the necessary information will be taken. The customers and suppliers will be able to track the vehicles, which have GPS/RTLS in order to location its position in real-time.

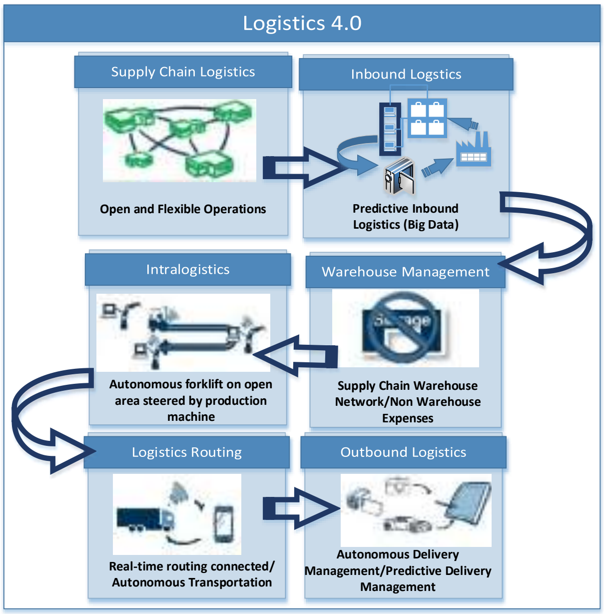

Fig. 2. Supply chain management process of logistics 4.0.

III. Technical Components of Logistics 4.0

Logistics 4.0 needs the support from the rapid development of many technologies, for example, smart sensors, big data/data mining technology, could computing, mobile internet technology and intelligent robots and AGV systems. We will not introduce all technologies that support the development of logistics 4.0 system in this paper. The following basic technical components of Logistics 4.0 are introduced. Among these are technologies of automatic identification, real time locating, smart sensing, networking, data analyzing, and business service.

A. Automatic Identification

Automatic identification for the development of a highly automated data collection technology is based on computer technology, optical, mechanical, electrical, communications and other technologies. It automatically acquires the object recognition information through the application of certain of the identification device to provide a technique for background processing system to complete the related follow-up treatment. It can help people quickly and accurately and automatically capture massive data input, and transport, warehousing, distribution and other aspects have been widely used. Automatic identification technology has developed into a comprehensive technology by the bar code identification technology, smart card identification technology, optical character recognition technology, radio frequency identification technology, biometrics and other components, and is in the direction of integrated application development.

Barcode technology is currently the most widely used automatic identification technology. Radio frequency identification (RFID) technology is developed in recent years, modern automatic identification technology, which is the use of induction, radio waves or microwave technology for radio frequency tag reader device for non-contact type reading, to achieve the purpose of automatic data acquisition. It can identify fast moving objects and you can read multiple objects with ruggedness, strong security features.

B. Real-time Locating

Real-time locating systems (RTLS) are applied to automatically identify and track the location of objects or people in real time, usually within a building or other contained area. Wireless RTLS tags are attached to objects or worn by people, and in most RTLS, fixed reference points receive wireless signals from tags to determine their location. Examples of real-time locating systems include tracking automobiles through an assembly line, locating pallets of merchandise in a warehouse, or finding medical equipment in a hospital. Event and products identification is often associated with recording the place of identification, real-time locating systems (RTLS) have to be distinguished from identification. There is a wide variety of systems concepts and designs to provide real-time locating: The following different locating methods and combinations for RTLS are known, such as: Angle of arrival (AoA); Line-of-sight (LoS); Time of arrival (ToA); Multilateration (Time difference of arrival) (TDoA); Time-of-flight (ToF); Two-way ranging (TWR) according to Nanotron's patents; Symmetrical Double Sided – Two Way Ranging (SDS-TWR); Near-field electromagnetic ranging (NFER) and Amplitude (RSSI, received signal strength indicator) triangulation.

C. Smart Sensing

The remaining basic requirement of logistics is to provide logistic goods in the "right condition". Smart sensors are used to detect the condition of goods or changes in its environment, and then provide a corresponding output for the purpose of decision-making. Typical sensors used in Logistics are:

- Temperature sensor;
- Humidity sensor;
- Ethylene sensor;
- Active RFID transponders
- others

The three technologies RFID, RTLS and smart sensors in combination fulfil a control function for the requirement of the "7R" in logistics. The "right product" has been identified, "right time", "right quantity", "right quality", "right price" and "right location" have been recorded and the "right condition" has been checked through smart sensors.

D. Networking

The Internet of Things (IoT) is the network of physical devices, vehicles, buildings and other items - embedded with electronics, software, sensors, actuators, and network connectivity that enable these objects to collect and exchange data This leads to a coalescence of material flow and information flow and enables every item to manage and control its logistic process.

The "Internet-of-Things" is an example of a technology that has not yet reached the status of being commercially available. Certain parts are available, but still there are many open questions left.

E. Data analying

Real-time big data is not just a process for storing a huge amount of data in a database or data warehouse. Data mining enables you to analyze and discover patterns, rules and knowledge from big data collected from multiple sources. So you can support decision making process. [13]

Data warehouse in the mid-1980s, it is a subject-oriented, integrated, nonvolatile, time-varying data collection, the data warehouse is to target different sources, different from the structure of the data after processing in data warehouse store, retrieve and maintain its support for a comprehensive, high-level analysis and processing, and large amounts of complex data in decision support. Data Warehouse so that the user has the freedom to extract any data, without interfering with the normal operation of the business database. Data mining is from a lot of, incomplete, noisy, fuzzy and random data in practical application, dig out the implicit, the unknown, the decision-making potentially valuable knowledge and rules of procedure. Generally divided into descriptive data mining and predictive data mining two kinds. Descriptive data mining includs clustering and association analysis, predictive data mining includs classification, regression and time series analysis. Its purpose is to data analysis, synthesis, induction and reasoning in order to reveal the relationship between events, to predict the future trend of development, decision-making basis for the decision makers.

F. Intenet for business service

A business service is a commercial transaction where one party grants temporary access to the resources of another party in order to perform a prescribed function and a related benefit. As an example, think about logistic services. The traditional service is about granting access to some socio-technical resources to ship something from one point to another. With digital media, the information flow associated to the material flow became more and more important. As an example, information about delays in just-in-time delivery is almost as important as the material flow itself. Even without introducing a strict metric, it is intuitive to say that the digital footprint of just-in-time logistics is higher than in traditional transportation.

Resources may be humans workforce and skills, technical systems, information, consumables, land and others. The Internet of Services (IoS) enables service vendors to offer their services via the internet. [14] The IoS system may consists of business models, an infrastructure for services, the services themselves and participants. Services are offered and combined into value-added services by various suppliers. They are communicated to users as well as consumers and accessed by them via various channels.

IV. DEFINITION

Logistics 4.0 is the use of bar codes, radio frequency identification technology, sensors, global positioning systems and other advanced networking technologies through information processing and network communication technology platform. These technologies are widely used in logistics transportation, warehousing, distribution, packaging, handling, and other aspects of basic activities. Cargo automation and efficient operation of the transport process improves management and service level of logistics industry, lowers costs and reduces consumption of natural resources and social resources. Here we give a general definition of logistics 4.0 as the following:

logistics 4.0 is a collective term for technologies and concepts of value chain organization. Within the logistics, CPS monitor physical processes, create a virtual copy of the physical world and make decentralized decisions. Over the IoT, CPS communicate and cooperate with each other and humans in real time. DM discovers knowledge to support decision-making process. Via the IoS, both internal and cross-organizational services are offered and utilized by participants of the value chain.

With logistics 4.0 that can analyze and make predictions based on real-time, real-world information, our ability to synchronize events and interactions becomes much more precise. We will be able to take immediate action if sensors tell you that materials have been mishandled or that shipments are encountering delays. With greater insight and the ability to respond in real time, you can optimize the layout of your entire logistics network, improving costs, performance, reliability and ultimately customer satisfaction.

V. CASES OF LOGISTICS 4.0

We are working some feasible studies in Knowledge Discovery Laboratory, at NTNU. In this paper, we will show two cases: one is related to the function of identification, and another is related to the function of real time locating in logistics 4.0.

A. II-RFID (Intelligent and integrated RFID) stsrem

With the development of the RFID technique, it became increasing possible to acquire real-time production and logistics data. However, it is far from sufficient for the company only to collect the massive amounts of RFID data and do the track and query. RFID data-based decision-making will provides more value to the company and improves the production and logistics efficiency. Thus, an Intelligent and Integrated RFID (II-RFID) system [15] is proposed, which combines the RFID data acquisition with decision support based on data mining.

1) II-RFID System Architecture

As a highly automated data acquisition and decision support system, the II-RFID system comprises six levels as shown in Fig. 3:

1. Assets level, which contains products (from materials to finished goods), conveyor belts, machines, pallets, packages and shelves, etc.

2. Data acquisition level, which consists of RFID tags, antennas, readers and middleware.
3. Control level, which consists of PCs, middleware and other network devices used to connect the equipment.
4. Database level, which combines RFID database and other high level databases.
5. Decision support level, which involves data mining approaches or computational intelligence for decision making, and
6. Management Level, which is the intended final endpoint for the construction of an II-RFID system.

As shown below, an II-RFID system includes the company assets, the RFID system, the production management system and the decision support system. The final goal of the II-RFID system is to discover knowledge from RFID data for the manager as a reference.

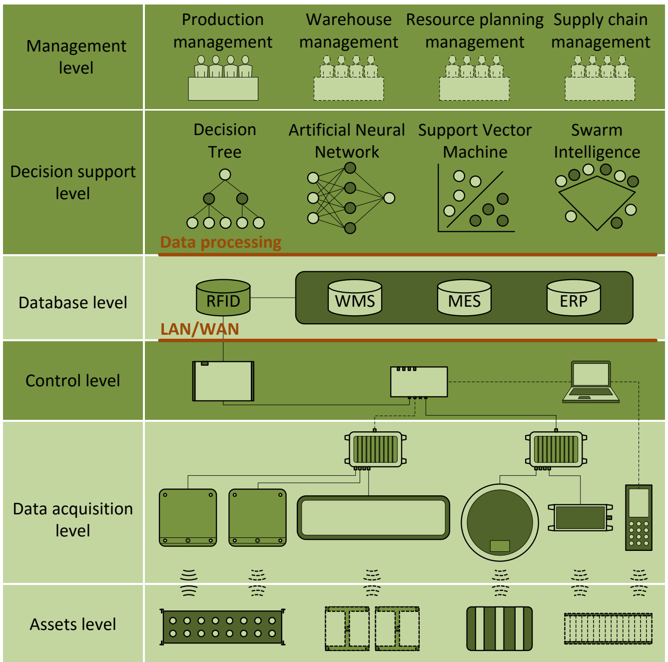

Fig. 3. System architecture of II-RFID system

2) Functions of the II-RFID System

The II-RFID system works on the foundation of the real-time collected RFID tag information. The following tasks based on RFID data acquisition can be achieved:

- Online part information collection
- Online processing progress statistics
- Daily processing capacity statistics per station
- Total processing time for a batch of product and processing time of each working process
- Production progress visualization and remaining processing time prediction
- Quality statistics (including scrap and recall)

Considering production management in the II-RFID system for instance, the main functions of the RFID production management system include WIP (working in process) management, processing station management, manufacturing process management, production task management, personnel management and tool/fixture management. Typical data collection and reporting include the following.

- WIP management: WIP registration; WIP inspection registration; quality query; product positioning and tracking, prediction of the remaining processing time.
- Processing station management: processing station registration, WIP of processing station query, processing station output query, process information query.
- Manufacturing process management: manufacturing process registration and query; manufacturing process management is the basis of production task schedule query.
- Production task management: production task registration and query; production task schedule query.
- Personnel management: personnel registration; personnel productivity and production query.
- Tool and fixture management: tools/fixtures registration; tool position allocation; maintaining proper maintenance schedule.

3) Implementation in Logistics 4.0

As described in the previous section, II-RFID system has a multiple level system structure. In the KDL the II-RFID system is implemented with both RFID hardware and software. The experiment equipment comprises infrastructure of a warehouse and production line, RFID data acquisition system and production management software. The layout of the RFID Lab is shown in Fig. 4.

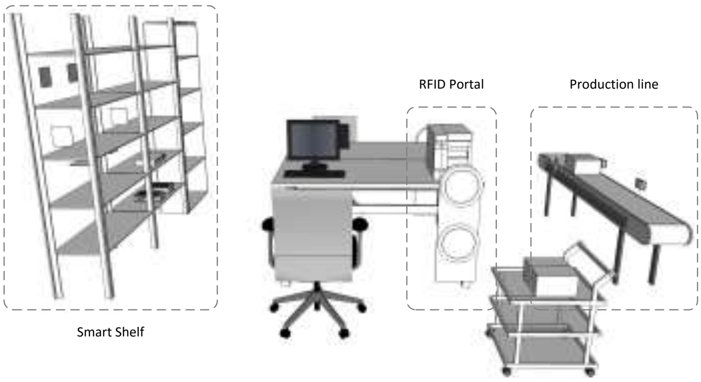

Fig. 4. RFID Lab layout

The RFID lab comprises three functional areas, which are the production line, the RFID portal and the smart shelf. Referring to the proposed II-RFID system architecture, the implementation of each system level is shown in Table 1.

TABLE I. II-RFID SYSTEM IMPLEMENTATION

System level	Implementation
Asset level	Assembly line, Pallet, Portal, Trolley, Shelf
Data acquisition level	RFID tag, RFID antenna, RFID reader, Handheld reader, Router/Switch
Control level	Middleware, Computer, Software
Database level	Local RFID database
Decision support level	Program on the basis of Computational Intelligence
Management level	Manager, Expert

Each functional area is installed with a variety of RFID antennas. One or multiple antennas are set to be one read point, to represent the location of the business step. For instance, the conveyor belt is used to represent the production line. Two antennas are assigned along the conveyor belt representing two working stations. The portal area consists of an Entrance and an Exit. Each portal is installed with two antennas to monitor the tagged goods passing by. The warehouse area comprises three shelves, where shelf 1 and shelf 2 are monitored by layer separately, while shelf 3 is monitored completely.

Thus, the RFID lab simulates RFID data collection both in the production line and warehouse, and the research will focus on inbound logistic in production management and warehouse management.

B. *RTLS (Real Time Location System)*

1) Principle of RFID RTLS system

Automatically identify and track objects or people usually within a production workshop or other contained area. Wireless RFID tags are attached to objects or worn by people and fixed to the reference points receive wireless signals from tags to determine their location. Configuration of the system in the lab is shown in Fig. 5.

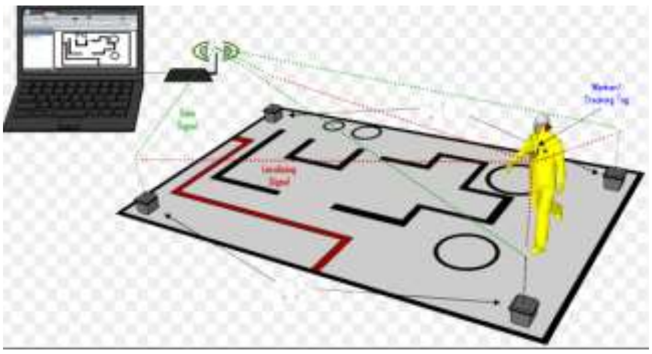

Fig. 5. The principle of RTLS using RFID in the lab.

2) Benefits of the system:

- To increase efficiency and degree of automation
- To reduce risk of errors and rework
- To increase productivity and savings
- To enable total traceability and visibility

3) ANN (Artificial Neural Networks) model

It is not necessary for the prior knowledge of the RSSI (received signal strength indicator) noise distribution and noisy RSSI measurements can be made use of directly for training the ANN model with the actual coordinate locations.

Fig 6. shows the ANN model which is capable of characterizing the noise and compensating for it to obtain the accurate position (coordinats).

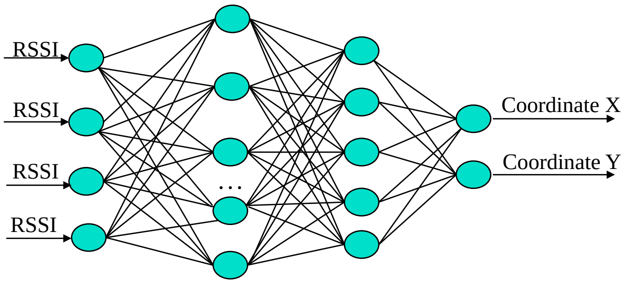

Fig. 6. ANN model for determinning of the real position of the objects

4) RTLS results of experiment

The experiment has been run in the lab. and indicates the following results:

- RSSI value provides a viable way for indoor location.
- Artificial Neural Networks are capable of predicting the location of vehicle.
- The prototype of indoor location system using passive RFID tag is cost-effective.
- The location of test vehicles is satisfactory with acceptable precision.
- The lab facility is easy for implement to other applications related to Logistics 4.0.

VI. LESSONS LEARNED

In order to understand what Logistics 4.0 really is, we list 10 lessons as the following:

Lesson 1:

Logistics 4.0 is more than CPS (Cyber Physical Systems). Logistics 4.0 is a complex system and responsible for meeting the requirement of huge trends and increasing complexity in logistics. That means logistics 4.0 can solve problems in flexible supply chains. It is not just limited to selected technologies; however, it must be understood as an integrated management concept. Logistics 4.0 system should consists of some basic technical components, such as CPS, IOT&S and big data/data mining.

Lesson 2:

Logistics 4.0 determines efficiency. It lowers transaction cost and enables flexibility within networks while realizing small batch sizes and scalable infrastructure.

Lesson 3:

Logistics 4.0 needs concept and a framework. A guiding framework supports decision making in terms of understanding and managing system complexity as well as closing the integration gap within the supply chain.

Lesson 4

Logistics 4.0 is based on knowledge discovery. In order to anticipate complex system behavior of logistics system, we need to apply the appropriate data analysis models/algorithms together with big data acquisition system. The knowledge discovered will support the business model of Logistics.

Lessons 5:

Logistics 4.0 has to be specific. Both the target operating model as well as implementation roadmap have to be developed individually for a specific corporate. Different company has their specific business model. It could not to be make a universal system for all.

Lesson 6:

Logistics 4.0 is an evolutionary process. It should stands right at the beginning. We will still have to do a lot of trial-and-error and develop new solutions while learning becomes a key success factor.

VII. CONCLUSIONS

A definition, the main technical components and some design principles of Logistics 4.0 has been mentioned in this paper, which may be useful for the industries to have a clear picture of what Logistics 4.0 means and define their strategy for future development.

Logistics 4.0 is a part of Industry 4.0 and it will promote the development of Industry 4.0. It is clear that there is no Industry 4.0 without Logistics 4.0.

The main challenges of development of a Logistics 4.0 system are that we need a transparent, decartelized, flexible, robust, dynamic, predictive and smart logistics system.

Logistics 4.0 is a new and unclear concept. The framework of Logistics needs to be researched and developed. It brings many opportunities for the development of new technologies and for huge business benefits. We may look at the big picture to have the prospects for the future, and start small step to contribute to the Logistics 4.0 gradually.

Future work includes building a test scenario in a laboratory followed by feasibility studies within real environments. NTNU will cooperate with SPU (Shanghai Polytechnic University) to develop a Logistic 4.0 demon system where a bicycle will be used as a test product.

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