Ensuring the Visibility and Traceability of Items through Logistics Chain of Automotive Industry based on AutoEPCNet Usage

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DOI: 10.15598/aeee.v14i4.1788

Abstract. *Traceability in logistics is the capability of the participants to trace the products throughout the supply chain by means of either the product and/or container identifiers in a forward and/or backward direction. In today's competitive economic environment, traceability is a key concept related to all products and all types of supply chains. The goal of this paper is to describe development of application that enables to create and share information about the physical movement and status of products as they travel throughout the supply chain. The main purpose of this paper is to describe the development of RFID based track and trace system for ensuring the visibility and traceability of items in logistics chain especially in automotive industry. The proposed solution is based on EPCglobal Network Architecture.*

Keywords

AutoEPCNet, Auto-ID, logistics, RFID, SAP R/3, supply chain, visibility and traceability.

1. Introduction

The main subject of the logistics is the management of material flow and the associated flow of information and financial flows. The aim of this procedure is to achieve a competitive service level as well as minimizing logistics costs. Instrument for achieving that objective is a corporate logistics system which is one of the support functions of the company.

The Service Level (SL) is the company's ability to respond to demands and it can be generally expressed as a percentage, for example, between the actual fulfilment of customer requirements and their original content.

Logistics costs can be defined as all funds that we have to spend in order to achieve a given service level.

The quality suppliers are needed for effective supply chain management. These suppliers have to deliver goods to a Distribution Centres in time and in the required quantity. For the evaluation of suppliers, so called Service Level is used, which testifies to the quality of these suppliers' services. It can be expressed as follows [1]:

$$\mathrm{SL}\,(\%) = \frac{\mathrm{NCD}}{\mathrm{NWD}} \cdot 100, \tag{1}$$

where NCD is number of correct deliveries and NWD is number of wrong deliveries.

It is expressed in percentage and indicates how many deliveries were correct in defined period of time. The SL is expressed for the month, and if it stays bad for a long time, various sanctions are usually applied. SL of less than 80 % is considered as unsatisfactory. The SL value of 95 % represents an exclusive supplier that is very desirable to have deeper relations with [1].

The complex structure of the automotive industry puts high demands on logistics and associated service level. The automotive industry is characterized by a large number of different kinds of products and high volumes of fluctuating production. Each supply chain has to meet high standards of quality and flexibility. One of the most dynamic trends that fundamentally affects the operation of companies in the automotive industry is the gradual substitution of original forms of communication by the new ones. Globalization, variability of demand, production on order, sequential deliveries and many other processes reveal shortcomings of traditional methods of communication and they are being replaced by new technologies, including already established Electronic Data Interchange (EDI) standard the EPCglobal Network begins to assert.

The primary impetus for the use of the EPCglobal Network for a communication between partners in the automotive industry is to reduce costs and streamline processes in the delivery of goods. If the logistics chain should work as a complex system and bring benefits to all stakeholders, it is assumed that most vendors will not only be able to supply in the JIT mode, but also that they will share their data and reports electronically with their own suppliers as well as with their customers. The shared data can then be used to print logistic labels, to compare different generations of order references, to generate order references for own suppliers, etc. Until recently, the high investment requirements were an obstacle to extend this model to all levels of the supply chain for the acquisition of an integrated system which would provide the mentioned functionality.

2. Related Work

Standards for Electronic Product Information Services (EPCIS) systems have been available for quite a long time. EPCIS could be considered as a key enabling technology to be primarily implemented in such areas where it is for any reason necessary to show the history of the production, transportation, ensure authenticity and higher level of safety of the products.

Typical areas corresponding to the above description, are pharmaceutical industry, transportation, processing and storage of drugs and preparation of consumer units of medicines in order to clearly demonstrate their pedigree and traceability of individual consumer packages.

Dozens of countries are trying to implement drug supply chain regulatory requirements nowadays. Most of the products are under a government reporting requirement. For example, USA order the compliance information exchange between trading partners in pharmaceutical industry. Rather than dictating the data formats and mechanism for the data interchange, the FDA has left it up to industry to decide.

One of the logistic data exchange options is the precise use of the systems based on the EPCIS and other EPCglobal standards and interconnection of the logistic data. Another option is to use Advanced Shipping Notice (ASN) that is a part of the EDI system.

The EPCIS is one of the most interesting possibilities for interchange of serialized data. EPCIS has not yet been much used for exchanging lot-level compliance data. Most of the wholesale distributors have accepted it in the past. Most of them prefer to receive ASNs that deliver logistical information in addition to compliance data instead. In 2014 pharmaceutical companies started the implementation process of the HDMA ASN 856 Guideline for lot based Drug Supply Chain Security Act (DSCSA) requirements and this soon after that became an industrial standard. As drug stores and hospitals are connecting to the system, the adoption of the ASN has continued [2].

EPCIS is not the official format for exchange of serialization data in the US, but supply chain partners may still choose to exchange data in this format. As we mentioned above, EPCIS was especially designed to exchange large volumes of serialized data. If anyone chooses EPCIS standard implementation, they have to decide if they would use EPCIS to exchange compliance data together with ASNs, or would the logistical data be included in the EPCIS communication avoiding the use of ASN. Many within the industry feel that the two should co-exist, with EPCIS serving purely a compliance purpose and ASNs managing logistical data, which was their first purpose.

Because there are already verification requirements for the entire supply chain in regards to returns, some manufacturers have begun to express that they would like to send consumer unit level serialized data prior to 2023, when they are required to do so. The serialization itself should start in 2017.

It is a beneficial to think of EPCIS adoption beyond simply meeting the compliance date. Since sooner or later they would like to offer the traceability service of each product, the investments in system covering both tasks would be smaller than investment in both systems one by one. According to a recent Acsis survey, researchers cautioned manufacturers taking a "compliance now" approach that they may get caught with long-term costs and rework of initiatives to build a truly traceable, serialized warehouse. In general, unit level serialization can protect brands from risk in a variety of ways, including improved recall readiness, and providing the ability to document chain of custody which helps eliminate opportunities for counterfeit drugs to circulate through the supply chain. By failing to recognize the long term pros, companies can risk lowering productivity through disintegrated systems and additional manual processes time and costs [3].

3. EPCglobal Network Architecture

In order to implement delivery of individual products and state of their lifecycle in the logistic chain, to ensure the information flow across information systems of the individual parties who are involved, it is necessary to use the Electronic Product Code Information Services (EPCIS) standard and other EPCglobal standards.

The EPCglobal Network is a set of technologies, enabling business partners to monitor product movement in the logistic chain. EPCglobal Network, supports improvement of organizations efficiency by enabling dynamic and accurate information distribution (i.e. information about the product movements) in real time.

EPCglobal Network comprises:

- Object Naming Service (ONS),
- EPC Discovery Services (DS),
- EPC Security Services (SS),
- EPC Information Services (EPCIS).

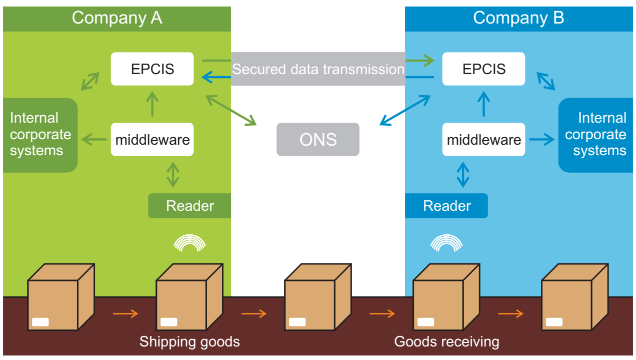


Fig. 1: Example of EPCglobal architecture.

The EPCglobal Architecture Framework includes software standards at various levels of abstraction, from low-level interfaces to RFID reader devices all the way up to the business application level [4].

3.1. EPC Information Services

The goal of EPCIS (EPC Information Services) is to enable applications to create and share visibility event data, both within and across enterprises. Ultimately, this sharing is aimed at enabling users to gain a shared view of physical or digital objects within a relevant business context. EPCIS is a GS1 standard [5] that enables trading partners to share information about the physical movement and status of products as they travel throughout the supply chain of trading partners - from business to business and sometimes even to consumers.

The EPCIS Capture Interface acts as an interface between the "Capture" and "Share" data. The EPCIS Query Interface provides visibility event data both to internal applications and for sharing with trading partners.

The Back-end Application is software system consisting of databases and information systems, addressing the different business areas, from regular monitoring and reporting process of reading up to complex solutions of logistics chain traceability. These systems play a crucial role in implementation of traceability and visibility services because there is a necessity to develop interface for data exchanging between RFID system and Enterprise Resource Planning (ERP) systems. Section 5 deals with this issue.

Generally, EPCIS processes two kinds of data: event data and master data. Event data arises in the course of carrying out business processes, and are captured through the EPCIS Capture Interface and are available for query through the EPCIS Query Interfaces. Master data are additional data that provide the necessary context for interpretation of the event data.

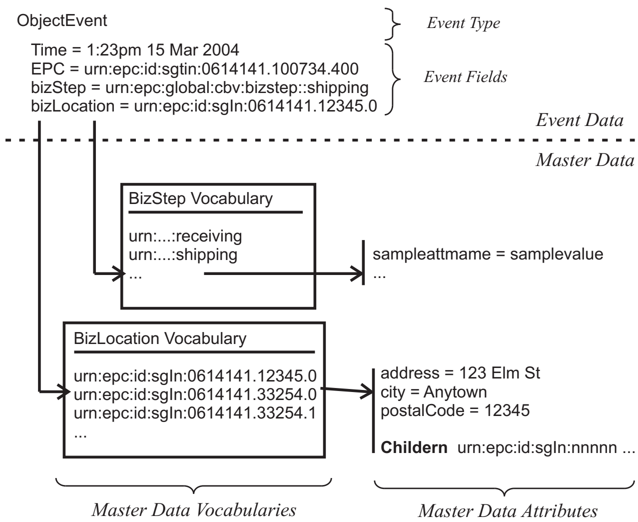


Fig. 2: Event and Master Data [5].

The basic element of the whole EPCIS system is event-driven data processing. As an event we can understand the real event usually associated with the process in the logistic chain accompanied by RFID identification. The event must be presented in a form that is understandable for software components, so it is realized through a standardized XML document. Events may relate to the identification of one or more objects which are identified by the EPC, the aggregation of objects into higher logistic units, business transaction or a simple inventory quantity of objects of that type.

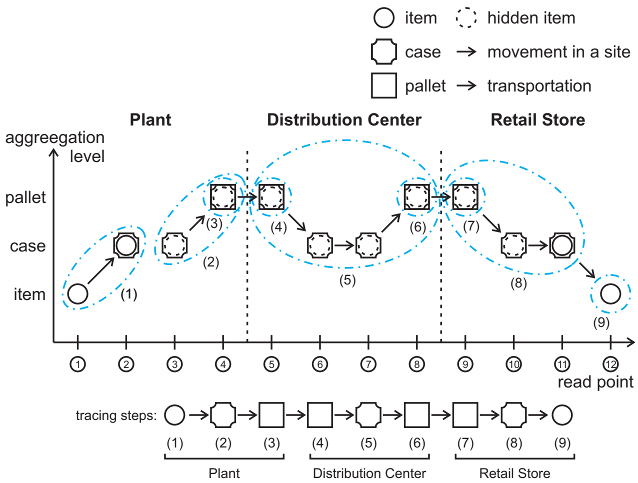


Fig. 3: Business process showing generation of EPCIS data.

The information in an EPCIS event records the essentials of what happened during a step of a business process in which physical or digital objects were handled, expressed via the four dimensions of **what**, **where**, **when**, and **why**.

4. Developed Solution

The developed solution fully respects the rules concerning the standardized communication within EPCIS that was discussed in the previous sections. The vision of an integrated management system and visualization of lifecycle was primary overall concept of this system purpose. The essence of the project was to increase the efficiency of the process of tracking and tracing objects in order to maximize efficiencies in the supply chain. On the basis of observed information, it will be possible to create substantial added value in terms of providing information services to its business partners.

Based on the analysis of communication standards of the best-selling UHF RFID readers, it was decided to use the LLRP standard [7] defined by the GS1 organization in the EPC Architecture of the Framework System EPC Global.

There are various traceability needs in industry, which defines the different functional requirements of the traceability services, as was mentioned by Kang in his article [8]. Although traceability requirements are different for various industries, there is a common fundamental requirement - traceability for serial-level (or item-level) product [9], [10] and [11]. Based on this serial-level product traceability, companies in the manufacturing industry emphasize the traceability for manufacturing lots or batches, and the traceability for operation conditions, as they are to identify potential sources of quality problems of defective products.

Large manufacturing industries, such as automobile industry, require packaging information about an item such as bill-of-material information. Similarly, logistics companies have to obtain aggregation information between items and logistics units such as pallets and cases [12] and [13].

4.1. AutoEPCNet Conceptual Scheme

AutoEPCNet is an information system to track and trace items marked with RFID tags in logistic chain. The main function can be characterized as follows:

- processing large-scale RFID event data, such as in-bound and out-bound logistics data,
- enabling history trace services tailored to the auto industry logistics system,
- building an information service hub by harnessing RFID technology.

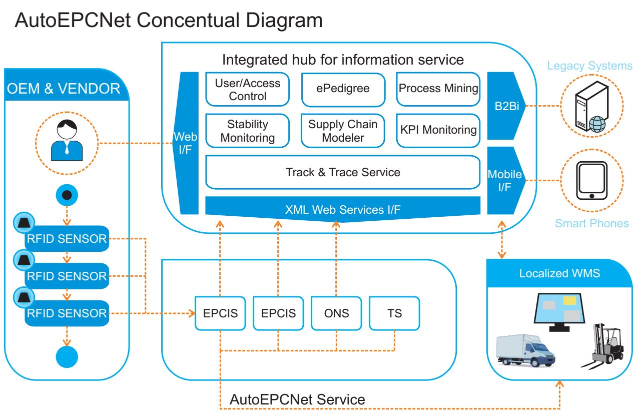


Fig. 4: Conceptual scheme.

As can be seen in Fig. 4, the system architecture is composed of the following crucial layers. The first important layer is called "interface" layer and it is responsible for receiving and interpreting users' requests. The second layer, called "business logic" layer, has the core functions for the queries that will be described in the

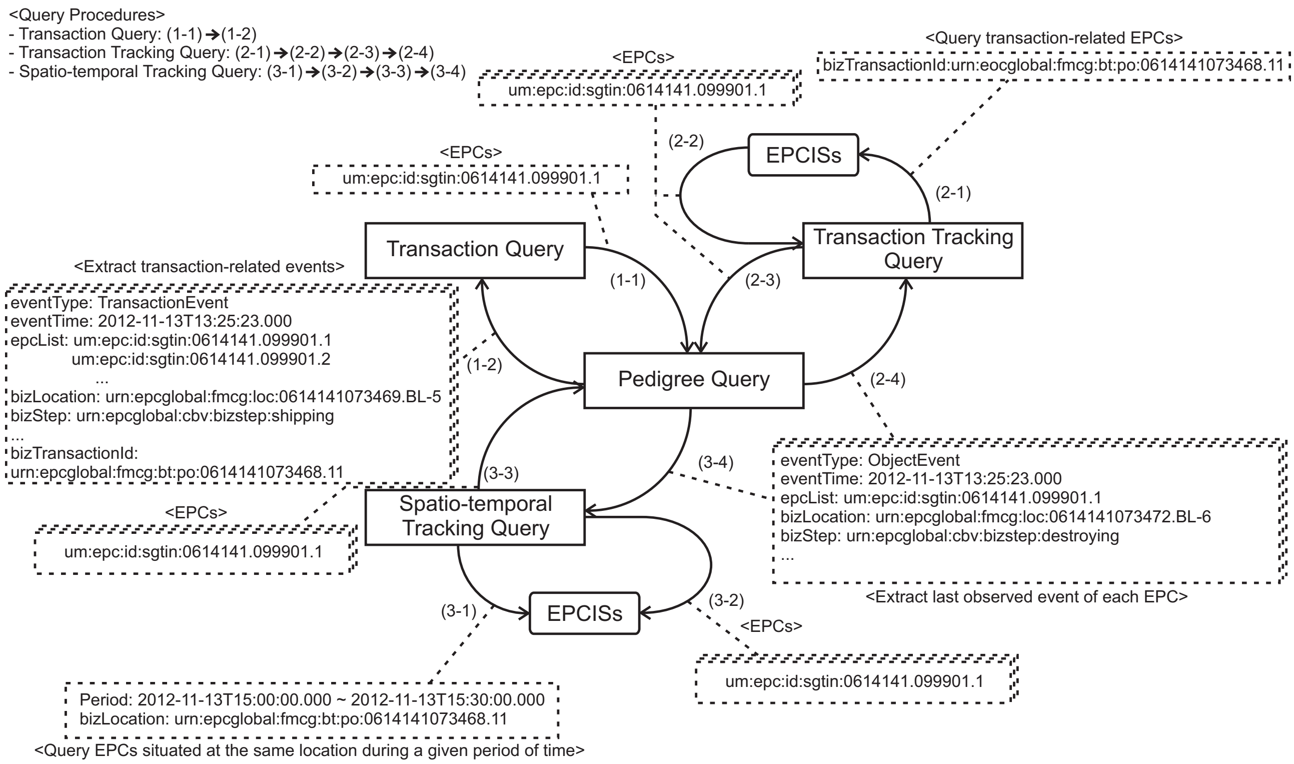


Fig. 5: Information flows among the TS queries.

next subsection. And the last one, called "EPC client" layer allows the core functions of traceability service to invoke EPCglobal services such as EPCIS, DS and ONS. Thanks to use of multi-threading it was possible to implement the EPCIS invocation that enables that multiple EPCIS's can be called simultaneously. The separation of business logic and EPC client allows developers to accommodate any possible changes of the EPCglobal network services. The web-based Graphic User Interface (GUI) for supporting users' accessibility in the form of an RFID information portal system was implemented by the Korean colleagues.

Based on the traceability requirements analysis and based on earlier studies and industry survey, we have defined a set of essential RFID traceability requirements which are as follows.

There was developed a set of efficient algorithms for implementing the Traceability Service (TS) queries. The algorithms are based on the following two assumptions on the EPCglobal network operation, both are reasonable ones:

- Every EPC must be reported to DS at the first observation and the last observation within a site (e.g., a warehouse or a manufacturing plant).
- Once a given (child) EPC is aggregated to other (parent) EPC, the EPC can have neither a new child EPC nor a new parent EPC until disaggregated.

The event information (called EPCIS event) plays an important role in the query algorithms. In order to process the queries, TS needs to collect DS records, each of which contains the information on the EPCIS that a specific EPC has visited, and EPCIS events of different types (*ObjectEvent*, *AggregrationEvent* and *TransactionEvent*) [8].

1) Pedigree Query

The pedigree query is to reconstruct the complete history of individual products or other logistic units [13]. The typical usage of this query is to obtain an answer to the following questions: What is the full history of detections of item 123? Where and when was the item 123 lastly detected?

The procedure to retrieve the entire history for a given EPC is composed of two steps. The first step is to request all the event data of the EPC of interest (e.g., an item) to EPCIS's. A second step is to retrieve all the parents (e.g., pallets, containers) information if the EPC had parent(s).

2) Transaction Query

The transaction query is used to find the business transaction identifiers (e.g., purchase order, invoice and package) that were related to an item of interest during the lifecycle of an entire supply chain.

The algorithm of a transaction query is simple compared to a pedigree query algorithm. TS first executes a pedigree query with a target EPC, and then extracts business transaction-related events, which has a non-null bizTransactionList field. The query users can easily list up the business transactions in which the target EPC has involved through the supply chain by checking the bizTransaction field of each event.

3) Transaction Tracking Query

The transaction tracking query is to find out the current location of items which were related earlier to a specific business transaction.

In this query algorithm, TS first collects all the EPC's (including items and containers) that are associated with a specific business transaction using the input parameters (epcisAddress, bizTransactionType, and bizTransaction), and stores them on the EPCList. Then, TS executes a pedigree query for all the EPC's on the EPCList and it stores the last events (informing of the current locations) of all the resultant events.

4) Spatio-temporal Tracking Query

The spatio-temporal tracking query is to search for the last locations of products which were once situated at the same location during a given period of time.

Using the algorithm of the spatio-temporal query, TS first executes a simple event query to a given EPCIS in order to collect all the ObjectEvent and AggregationEvent type events that occurred during a specific time period at a specific location defined by the readPoint. Then, TS executes a series of pedigree queries for all the EPC's extracted from the result of the simple event query, stores the last events of all the resultant events.

5) Aggregation Tracking Query

This query provides all the aggregation information of a product at a given period of time.

This query makes recursive function calls to search for the root EPC of a given (input) EPC and all the children of this root EPC at a given time (*dateTime*). First, TS determines the first EPCIS to be searched for the root EPC. This EPCIS is the last visited one before the given *dateTime*. Then the function *getRootEPC()* is used to search the root EPC of a given EPC. Finally, *getChildEPCs()* function is used to build up an , which defines the whole family pedigree of the input EPC in a tree data structure.

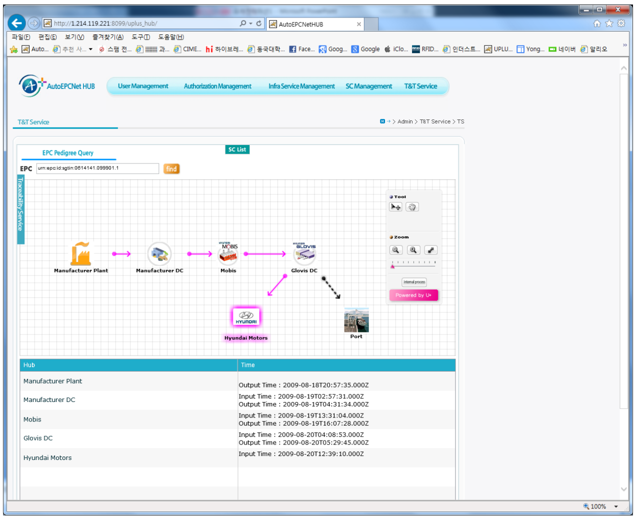


Fig. 6: Supply chain modeller.

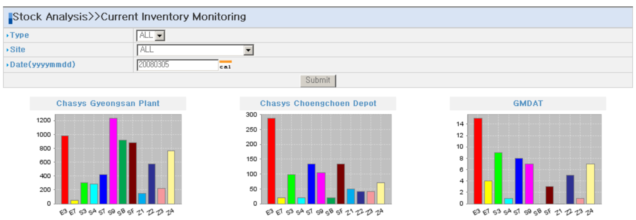
4.2. Supply Chain Modeller

The first part of developed solution is called Supply Chain Modeller. This is a module that is used for modelling the logistic chain and any linkages that take place therein.

This tool facilitates handling and logistical follow-up activities that take place in the chain and gives these activities in a clear and mostly coherent unit. The Fig. 6 shows the main screen where the user defines all the elements involved in the supply chain and integrate these elements by oriented edges for marking a sequence of logistic data. Software has a predefined range of graphic elements but for the user's purposes it is possible to create and upload their own graphics which will be more appropriate to their needs.

4.3. Visibility and Analytics Service

This part of the system offers to user information about the status of all the participants and creates their clear graphical structure. The whole process of the supply chain can be monitored in a form of graphs and thanks to them it is possible to see and detect downtime and



Site	Object Type	E3	E7	S3	S4	S7	S9	SB	SF	Z1	Z2	Z3	Z4	Total
Chasys Gyeongsan Plant	984	55	301	283	421	1231	917	883	148	576	220	762	6781
Chasys Choengchoen Depot	287	21	98	21	133	105	21	133	49	42	42	70	1022
GMDAT	15	4	9	1	8	7	0	3	0	5	1	7	60
Total	1286	80	408	305	562	1343	938	1019	197	623	263	839	7863

Fig. 7: Stock analysis - Current Inventory Monitoring.

loss of time in different parts of the chain, or you can view data on stocks or manufactured products.

The data can be interpreted in a synoptic charts, the program allows you to prepare any set of data needed for the application.

4.4. e-Pedigree Service

One of the most important and most used parts of AutoEPCNet is an e-Pedigree tool which describes all necessary data about the product. The information about all phases of the product development are recorded into the pedigree, such as all identification data of the producer (name, address, state, country) and of course product information (name, description, product code) and further information about the location where the product is sent.

As was mentioned before, various types of industry need various types of requirements on the logistics chain. The great advantage of this system is that it can display data from external sensors besides EPC reading in an individual reading place. It is also possible to visualize other additional information that includes data from sensors, temperature, humidity, altitude, shock, sensors, opening mail, etc.

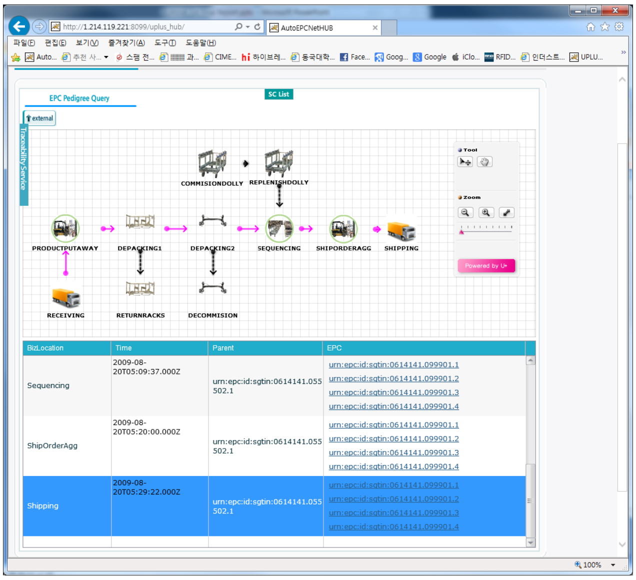


Fig. 8: e-Pedigree.

In every part of the supply chain there are the genealogy records information about the status and progress of delivery and thus the reliable and transparent functioning of the entire system is ensured. Through the genealogy, customer or one of the participating members can verify the authenticity of the product and make sure that the product has passed through all the stages that are necessary for its full value.

4.5. Technical Parameters

The whole tested system is run on two hardware identical servers - Intel Xeon CPU E5 2665 @ 2.40 GHz with 8 GB of RAM. Both have the Oracle 10g database and Tomcat 6.0.45 with Java (JDK 7u55) installed.

These are the minimum hardware requirements. When system runs continuously, the memory usage is around 75 % of its capacity.

There are servlets implementing the services of AutoEPCNet Hub, DS, TS and ONS with necessary databases (AutoEPCNet Hub and DS database) on the first server (epcis1). On the second server (epcis2), there are servlets for 6 instances of EPCIS implementation including the Capture and Query Interface and Core Business Logic along with EPCIS databases that are essential for deployment.

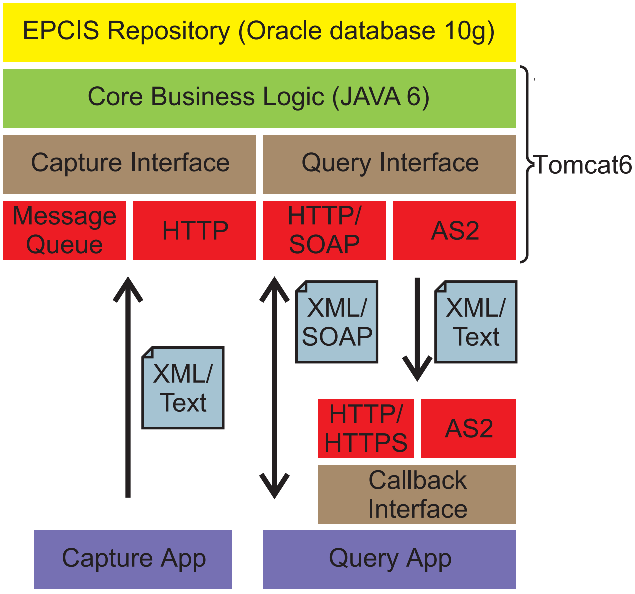


Fig. 9: AutoEPCNet architecture.

Functionalities of Capturing Application are:

- receives event data form Middleware or RFID reader,
- makes XML format of EPCIS event data based on pre-defined information,
- sends EPCIS event data to EPCIS capture interface (HTTP).

5. Mass Data Throughput Experiment

The developed solution has to process and record big amount of data from whole logistic chain. The objective of this test is to confirm whether the database storage can handle 1 TB of data.

In laboratory environment, we inserted event data approximately 1 TB (1 086 402 562 560 Byte). Using command '**db.stats()**', we can easily check the volume as follows. According to Fig. 10, the number of event objects is 990 720 040.


```
    "objects" : 990720040,
    "avgObjsize" : 10960,
    "dataSize" : 1086102562560,
    "storageSize" : 1123344417120,
    "numExtents" : 75,
    "indexes" : 1,
    "indexSize" : 32143535200,
    "fileSize" : 1179878686720,
    "extentFreeList" " {
    "num" : 0,
    "totalSize" : 0
    },
    "ok" : 1
}
```


Fig. 10: Checking the volume.

Using the '**db.collections.findOne()**' command, we repeated query for finding an event data 30 times.

All of queries returned within 30 seconds as follows. Each object includes eventType, eventTime, readPoint and so on. Using just single query, we can confirm all of event data we need.


```
mongos> db.Event.findOne();
{
    "_id" : ObjectId("566e2d21e4b03c99f5065a69"),
    "eventtype" : "Object",
    "event_id" : NumberLong(1),
    "eventTime" : ISODate("2012-12-10T09:00:00Z"),
    "recordTime" : ISODate("2012-12-10T09:00:00Z"),
    "eventTimeZoneOffset" : "+9:00",
    "action" : "Add",
    "bizStep" : "urn:epcglobal:cbv:bizstep:commissioning",
    "disposition" : "urn:epcglobal:cbv:disp:active",
    "readPoint" : "urn:epc:id:sgln:0614141150001.RP-1",
    "bizLocation" : "urn:epc:id:sgln:0614141150001.BL-1",
    "bizTransactionList" : {
        "type" : "urn:epcglobal:cbv:btt:po",
        "value" : "urn:epcglobal:cbv:btt:po:0614141150010.123"
    },
    "epcList" : [
        "urn:epc:id:sgtin:0614141.100000.1"
    ],
    "extension" : [
        {
            "fieldname" : "http://schema.hls.com/extension#temperature",
            "prefix" : "hls",
            "value" : [
                24.6295094935151
            ]
        }
    ]
}
```


Fig. 11: Confirmation of Event Data.

Using this test, we proved that our storage can handle 1 TB mass data and the Query Interface can provide visibility event data both to internal applications and for sharing with trading partners.

6. The Interface for Exchanging Data

The important aspect related to the implementation of RFID technology in the automotive industry was also to design and deploy a suitable additional simple system for the receiving gate in the car manufacturer warehouse - an interface for exchanging data between the AutoEPCNet system and corporate information system SAP R/3 for checking the received material. The system had to be connected to the SAP ERP interface and had to adopt GS1 standards with RFID reader communicating according to LLRP as well as EPCglobal RFID tags.

Applications for the reading gate include the following modules:

- **GB_GATE** - a module for reading data from the RFID reader. It provides continuous communication with RFID reader and sending and filtering data read from RFID tags and store them in a database.
- **GB_VIEW** - a module for data display and interaction with the operator. It provides information to the AT_INTF module when storing data in the database, sending information to module AT_INTF, saving the state change (completion of ASN filling, ASN manual termination). This module also provides data processing and status reporting of data from AT_INTF module (a list of items, the confirmation of processing ...), visualization of current data from the database. There is a submit button for sending reads into SAP and button for manual termination and confirmation of the storage command. Summary and statistics of activities can be also found here (in administrator mode).
- **AT_INTF** - a module for communication with SAP R/3. This module launches the RFC function for obtaining ASN items based on storing the first record with the new ASN into the database and store new ASN items into the database. It also launches RFC functions for accounting. The module launches RFC functions for termination of ASN processing or based on manual intervention. The module sends a confirmation about identified handling units into SAP and sends the request to accounting for incoming material.

7. Summary and Discussion

The system was tested at university environment [14] and in local automotive companies and brought

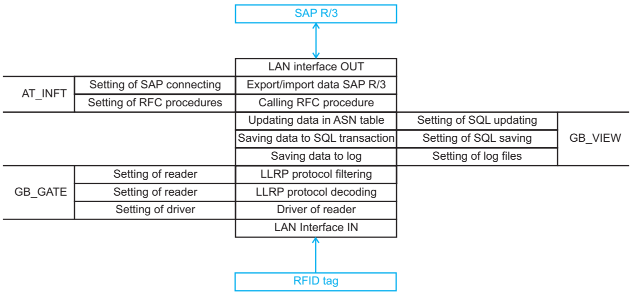


Fig. 12: Modules and theirs functions.

promising results. Together with the Koreans we are working on a gradual implementation to the automobile industry companies supply chain.

We deployed the simplified version of developed solution in logistic chain of car producer in Czech Republic. During the test period we can say that the main benefits of the solution are time savings and increase of Service Level (SL). The intended time savings relate to the time of delivery of material to the warehouse from unloading at the gate. Based on one-month testing process the time savings have been 29.71 minutes. This is due to fact that if the material is unloaded it can be directly moved to the warehouse. When the identifier of received material is in form of label, the delivered material has to be unloaded near the gate and when all incoming palettes are unloaded from truck, the worker in the warehouse is equipped with PDA containing application and he has to read all items one by one and send a command to SAP for receipt (GR) after reception end. After this, the material can be moved to warehouse.

Based on observation and evaluation of one-month system testing in real environment and according to Eq. (1), there was an increase of SL of 0.87 % compared to previous month. To respect the confidentiality, we cannot say the exact number.

8. Conclusion

In comparison with the automotive the serialization requirements occurred a little bit sooner in the pharmaceutical industry. So we can presume the future development of traceability services in automotive industry will be analogous. Sooner or later, it will be necessary to make each important part of car traceable and with compliance ensured by pedigree standards.

The automotive industry is one of the most complicated, the fastest growing and most turbulent, which is associated with high costs and investments. The automotive industry is a very strong competitive environment and any hesitation entails high costs. The current state of the automotive industry requires faster deliveries of increasingly complex products, throughout the supply chain from all manufacturers and subcontractors.

Due to cost reduction the automotive industry was the first, where the approach to organizing and managing processes (Lean Production) has begun to apply. The biggest losses of producers arise from overproduction, stock holding of materials, semi-finished products or finished products and last but not least also the loss due to suspended production because of delayed deliveries of goods.

The developed solution can help to meet strict requirements of automotive industry, ensures the traceability and visibility through logistics chain as well as helps to find bad habits of employees.

When the system was deployed at the producer of headlights we discovered very interesting phenomena during the first day of testing. When the pallets with headlights were despatched, it was found that the number of lights on a pallet disagrees with order. When all boxes were opened it was found that some headlights weren't marked by RFID tag. This situation was caused by employees who have hidden headlights and at a time when they are not able to meet the standards they take the headlights from their stocks. This is obviously undesirable condition since the date of production and batch does not correspond to reality.

Our system allows the user to model arbitrarily complex logistic chain geographically throughout the world. It is compatible with most of the UHF RFID readers, antennas and tags utilizing standards. The system allows you to visualize the flow of processes in real time and enables traceability of each EPC system. Provides clear graphical reports and outputs allows you to display data from sensors of physical quantities (temperature, humidity, shocks, etc).

Facts mentioned above show promising results for implementing of developed RFID-based track and trace solution that can be effectively deployed in various industrial and business areas such as asset management, supply chain optimization/visibility, order and delivery management, inventory management, and manufacturing optimization.

Acknowledgment

This contribution was supported by the Ministry of Education, Youth and Sport as a part of an Eureka international project titled "RFID Technologies in Logistics Networks of Automotive Industry" - identification number LF13005, international project code: E!7592 AutoEPCIS.

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