FACTA UNIVERSITATIS
Series: **Mechanical Engineering** Vol. 4, N° 1, 2006, pp. 63 - 74

RFID MIDDLEWARE AS A CONNECTION BETWEEN MANUFACTURING PROCESSES AND ENTERPRISE LEVEL INFORMATION SYSTEM

UDC 681.518:65.011.56

Dragan Šešlija, Zdravko Tešić

Faculty of Technical Sciences, Novi Sad, Serbia
dseslija@uns.ns.ac.yu

Abstract. *Manufacturing enterprises spend a lot of resources on real-time understanding where and in what state of manufacturing process the work piece/product is. Barcode readers can move data from paper to computing systems but they cannot be changed once printed on a label. As a result, work piece/product needs relabeling and the possible automation is very limited. RFID technology offers extensive capabilities for changing work piece/product data in real-time and within processes, and increasing visibility. By applying RFID technology across the manufacturing processes, managers can integrate the new information captured by RFID. Manufacturing Execution System can be updated to deliver real-time information flow to drive manufacturing execution. In this paper an effort is made for better understanding of RFID middleware as a key component for the successful RFID application and integration within broader factory information systems like ERP.*

Key Words: *RFID Middleware, Manufacturing Execution System, ERP*

1. INTRODUCTION

Effective Enterprise Resource Planning - ERP requires that management processes across the company, including marketing, product development, sales, manufacturing and finance should be integrated. The fundamental purpose of ERP is to establish a process that links demand plans to supply plans so that all the resources of the company are utilized in the most efficient and effective way. Such integration is the only way to get the performance and responsiveness that manufacturers require. Some estimates are that executives are getting only half of what they want from their ERP systems because of limited access to plant-floor data [1]. Due to the lack of integration the empty space in the middle is causing production to be delayed. Connecting plant floor and business systems in a robust way is a critical business issue for manufacturers today.

Received May 29, 2006

RFID technology provides a method to close some functional gaps particularly related to tracking and compliance management. By applying RFID and combining it with manufacturing information systems, both ERP and MES, a more potent information supply can be created that can drive production efficiencies, quality, asset utilization, productivity and the like, to much higher levels. The most common application of RFID technology today is for tracking goods in the supply chain, tracking assets and tracking items/products from a manufacturing production line.

Adoption of EPC (Electronic Product Code) and deploying RFID infrastructure is creating significant new requirements from a software perspective. Early focus on this technology has been on the physical and hardware side (readers and tags) but now, when standards are becoming better defined, the focus is turning to the software. As a result, a bucket of software referred to as ″middleware″ is needed to make all these new devices work together with the old ones. Those systems include but are not limited to MES (Manufacturing Execution Systems), ERP (Enterprise Resource Planning), WMS (Warehouse Management Systems) and SCM (Supply Chain Management). As very complex systems are in question, a lot of precision work will be required to be able to coexist and enhance the value delivered by the installed infrastructure. Currently, RFID is integrated in almost all aspects of up to date manufacturing processes; with new needs in the middle of existing platforms, new software functionality is required. Benefits will be large; many ERP installations have not produced the expected results because only less than 5% of facilities are integrated as they should be [2].

In this paper we will try to give a more functional view of what is required for efficient and reliable RFID application in manufacturing environment.

2. THE BASICS OF RFID

RFID technology is one type of automatic identification technology that uses radio waves to identify, monitor and manage individual objects as they move between physical locations. Although there are a variety of methods for identification of item/products with RFID, the most common method is by storing a serial number that identifies an item/product and its related information. RFID devices and software have to be supported by an advanced software architecture that enables the collection and distribution of location based information in real time.

A RFID system integrated in manufacturing consists of tag and interrogator (antenna and reader) and appropriate software for connection with the manufacturing/business applications are shown in Fig. 1.

RFID tags are small devices containing a chip and an antenna that store the information for object identification. Tags can be applied to individual product, pallets, cases or containers. The tags antenna transmits information to the interrogators antenna and to the reader. The reader converts the incoming radio waves into a form that can be read by a computer system. An RFID tag can be active (with a battery) or passive (powered by the signal emitted by the reader). Active tags are intended for long range distance reading and have high power and battery requirements. Passive tags can only be read from a short range distance, can be applied in high quantities to individual items and are lighter and less expensive than active tags.

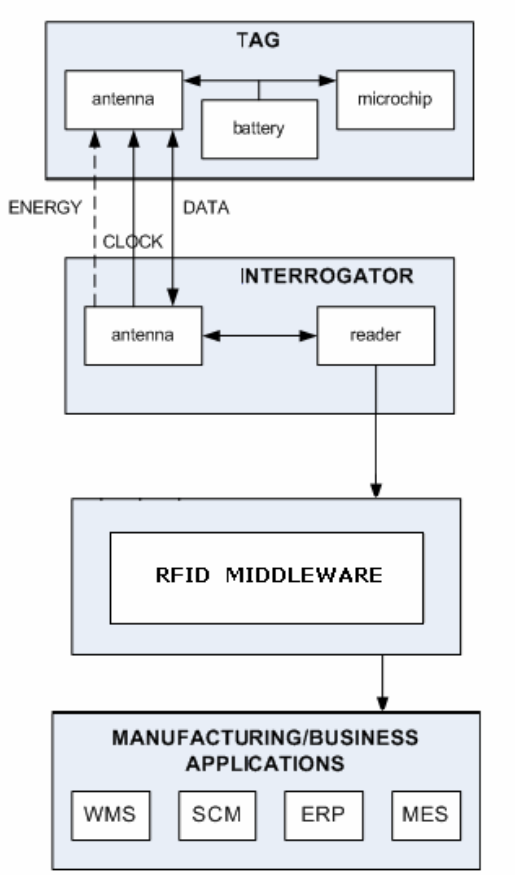


Fig. 1. Structure of an Integrated RFID Application

There are significant advantages to using RFID: tags are more durable than barcodes and can withstand chemical and heat environments; tags have read and write capabilities and can be updated, they can contain a greater amount of data compared to barcodes, and do not require human intervention. A comparison of applicable methods for data gathering is given in Table 1 [3].

In short, active RFID tags are battery charged and send a continuous or programmed interval message to a reader. Passive tags are not battery charged and do not send a constant or timed message. Passive tags are silent until they are charged by an antenna (which may surround a doorway or dock door) and at that time they wake up and relay the information contained in the memory through the surrounding antennae. The data are then pushed to a reader who captures the information. They require sophisticated software applications to sort and verify antennae reads.

While a barcode is seen though the 'eyes' of a data collection system, an RFID tag is heard though its 'ears'. While a barcode only has 14-16 digits, RFID allows 96 to 256 digits

on each tag, which allows a level of uniqueness that can identify products down to the shift, machine, and operator that produced them.

Table 1. Comparison of applicable methods for data gathering [3]

Attribute	RFID	2-D Matrix	Barcode
Technology	Radio frequency transmission	Optical	Optical
Line of sight	No	Yes	Yes
Read/write capability	Yes	Read-only	Read-only
Embed data	Yes	Yes	Yes
Reusable	Yes	No	No
Sensing distance	Varies, but < 15 ft.	Limited to inches	Limited to inches
Susceptible to false readings	Medium (High around high metal density environments)	Low, but contrast related	Low
Tag/label cost	High	Low, but dirt sensitive	Low, but dirt and label damage sensitive

RFID tags can be read-only, write-once-read-many (WORM), read-write, passively read by an antenna/reader, or actively send signals, usually aided by a battery. RFID systems usually operate at three main frequencies: low frequency, which is below 1 MHz; high frequency, which is the 13.56-MHz universal frequency required worldwide for scientific instrumentation; and ultra-high frequency (UHF), which is over 800 Mhz. UHF allows longer range and is less costly, though it reportedly has some interference issues.

Read ranges for RFID tags can vary from 2 mm for flush-mounted tags in tooling applications to 2.4 GHz tags that can read at 300 meters. Memory sizes can range from 96-112 bytes up to 64 Kbytes, though more memory may require added power, such as a battery, to keep that memory active and accessible.

RFID is essentially an automatic data collection technology, rather than a control technology, but it can be integrated into control systems because it can read and write to those systems. While a barcode can help track an item, RFID can track and record events, parameters, and measurements. This means users can make decisions and actuate changes more quickly, such as finding an item faster if it does not pass certain test criteria.

Similar to traditional radio transmitters, RFID tags were historically brick-sized devices that cost about $100, usually monitored work in progress (WIP) in heavy-duty industrial applications, and were more capable, such as having longer ranges. 'Historically, read-write data stored on RFID tags also allowed the user to build machine that functioned as islands because the tags retained the recipes and other process data,

Most of inexpensive RFID tags today follow the Electronic Product Code standard and provide 96 bits of information. The 96 bits are split into 8 bits for a header (defining the partitioning scheme for the rest of the bits), 28 bits to identify the manufacturer, 24 bits to identify the product type (SKU code), and 36 bits for the RFID serial number. What the codes do not contain is the lot or sublot identification of the product.

There are several sets of standards that are being developed for different industries. There are national standards (ANSI for the US, BSI for the UK, China RFID WG), International Standards (ISO, IEC, ITU, UPU) and industrial standards (ATA, EIA, EPC). For our purposes we are going to focus on the ISO international standard and the EPC indus-

trial standard. In Table 2 are given bullet points regarding ISO, EPC and ATA Global standards.

Table 2. Sets of Applicable Standards for RFID Domain

ISO RFID Standards	EPC Global RFID Standards	ATA Global RFID Standards
- Technology standards: ISO18000 series cover both Active and Passive RFID technologies - Data Content: ISO 15418, 15434, 15459, 24721, 15961, 15962 - Conformance and Performance: ISO 18046, and ISO 18047 series for both Active and Passive RFID technologies - Application Standards: ISO 10374, ISO 18185, 11785	Standards for the assignment and encoding of identities for physical objects, locations, loads, assets, etc. - A federation of different coding schemes - Most based on existing EAN.UCC standards - Defined representations for Data interchange (text) RFID tag encoding (binary)	Standards to automate the business processes and information exchange associated with aircraft parts and material. - EDI Standards - File Transfer Standards - Auto ID Standards - Marketplace Database Standards

A new standard, UHF Gen2, was ratified in December 2004, to provide functionality missing in prior standards, especially for enterprise adaptation and support.

When applying RFID technology care must be taken about the characteristics of products to which tags are applied. Some of the products themselves tend to absorb, rather than reflect, radio signals. This requires thorough testing of different tags and readers as well as label media.

3. MANUFACTURING INFORMATION MANAGEMENT AND RFID

Manufacturing information management allows for the gathering, analyzing, and transforming of real-time data into information to continuously improve a company's level of productivity and performance. The real-time visibility and intelligence facilitated by the integrated solution translates into improved agility, quality, and efficiency by tracking and executing production operations through a closed-loop information exchange with the ERP system.

But the internal efficiencies do not stop there [4]. Others include: automatic generation of pallet tags based on system knowledge of serialized cases; a more precise ability to recall or hold a product; and simpler pallet tagging, because the RFID tags only need to be on the correct side of the pallet, rather than a much smaller area with conventional bar codes, to ensure correct reads.

Today, most plant floor systems return only summarized information to ERP systems, such as how many products were produced and the product lot numbers. For example, a food manufacturer may report only one set of information about a product lot, indicating the materials used, the amount produced, and the lot identification. If, instead, each container has a separate ID, then thousands of identification records may need to be exchanged for each lot produced.

Each RFID tag holds an individual serial number for each case, and the tag also is linked to a database that hold the production attributes of each product — such as the time it was made, the batch number, and which production line it was made on. From this, the producer knows precisely when every tag was applied and from what batch the pallet was produced.

Usually RFID tags are applied to the product late in the packaging stage, either added to the product or applied to the case or container. Because RFID tags are pre-configured, the lot and sublot information can be associated only with the RFID serial number late in the production process. Information collected in the packaging step must be combined with the shop floor information about lots, sublots, or batches, and then sent to the company's supply chain or ERP system. The amount of information that will need to be exchanged with the ERP system is too great for manual exchange, so automated integration between shop floor systems and ERP systems will be required. The method for information exchange will also have to be robust and operate without guaranteed communication access. Many plants are not even on the same continent as the ERP system and will have many occasions when they cannot communicate. This will require a new class of manufacturing IT integration architectures that are asynchronous and loosely coupled, based on message queuing systems with guaranteed delivery.

Implementing RFIDs will require new or expanded manufacturing IT systems. The systems will need to track and record every container produced (or every one labeled), and the systems must have reliable links to corporate business systems.

How and where the industry will use the new technology depends on the way how successful will be the synchronization of newly obtained data with both their ERP and MES systems. This challenge escalates as the RFID applications are increasing to a large number of products and facilities and as they include integration in broader Supply Chain Management systems. It becomes more complicated when there is a need to fit within an overall IT and network infrastructure with all requirements for security and complying with company and industry standards.

RFID technology has to be integrated with management information systems and that needs middleware software and technology to provide real-time connections between RFID readers and application software. Currently, the focus is on tracking advantage of open data standards and protocols in order to integrate disparate applications within manufacturing system for solving problems in particular processes. RFID readers can be connected with MES and ERP through PC or PLC equipped with networking modules as shown in Fig. 2.

Information is shared across enterprise and must be coordinated and executed in accordance with customer orders. Production managers have to take row data from RFID and determine how to get it into MES that control manufacturing. MES processes such as planning, scheduling, routing and control must be modified in order to collect and be responsive to RFID information. RFID information are used to ensure that the labor, operation, machine, tooling and items/products are available and ready to use at each processing step, thereby eliminating paper and reducing downtime. Work orders and process steps could be controlled and modified in real-time.

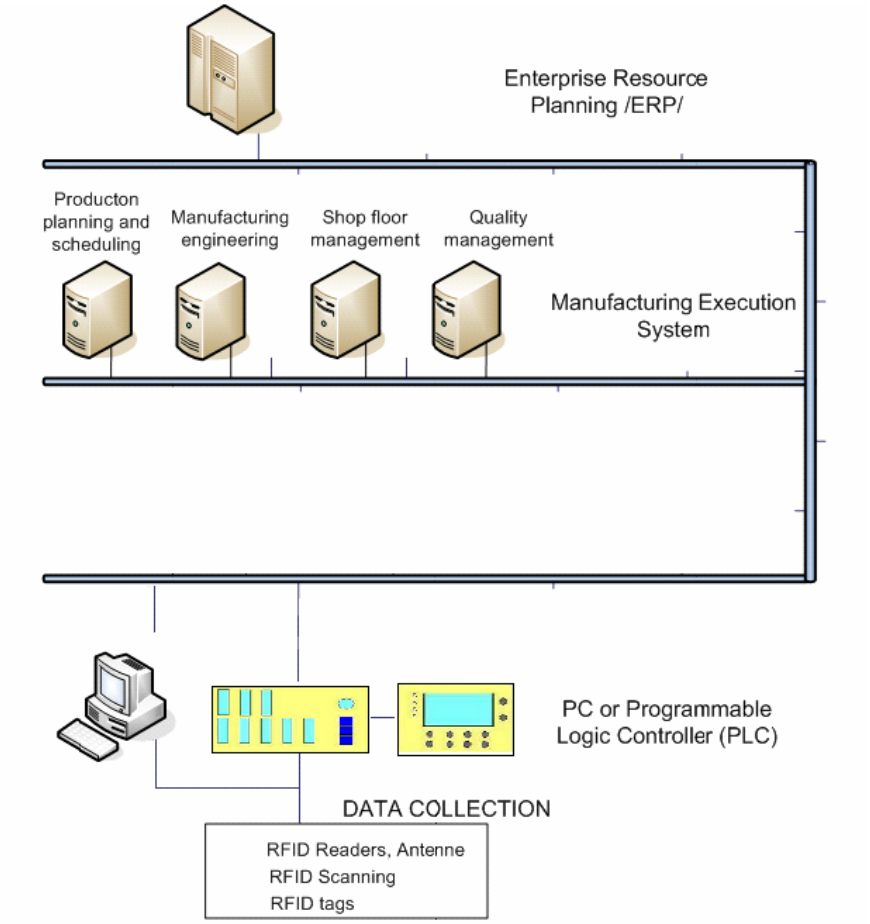


Fig. 2. Connection of RFID reader with manufacturing/business software applications

RFID middleware is software that links RFID devices to manufacturing execution systems, enterprise resource planning applications, warehouse management system and supply chain system.

The middleware software layer is required to deliver collected data from machines processing parts and assemblies and other devices equipped with RFID hardware. One such opportunity lies in the middleware layer for delivering collected information, regardless of the technology installed. Middleware is that layer of application software that can be connected through various methods to many machines to collect whatever data is required by the enterprise. Data collection, manipulation, filtering, sorting and networking fits barcode, 2-D, and RFID data capture requirements. Components of RFID middleware are shown in Fig. 3 and briefly described in [5, 6]:

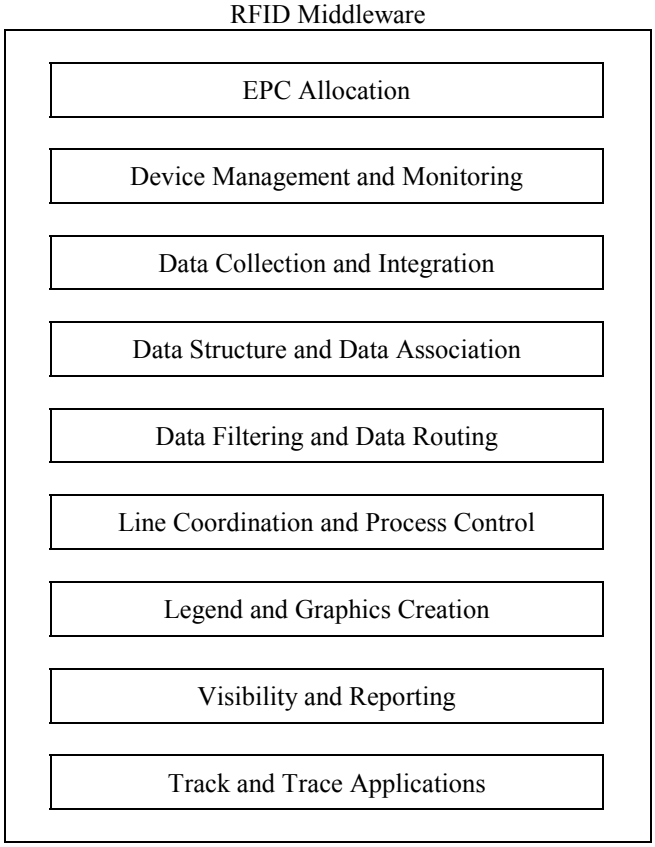


Fig. 3. Components of RFID Middleware

EPC Allocation

EPC will need to be managed on both the front side and back side of production (or tagging). Suppliers will be required to manage and allocate EPC information to their production resources on global, local and even production line level.

Device Management and Monitoring

As RFID tag encoding and application moves back into the manufacturing realm, a whole new set of devices will need to be managed, like weigh scales, desktop printers and other printing devices, validation stations and more. This will add to the application complexity as many of these devices are not based on the same EPC Global standards and will require unique individual device driver integration.

Data Collection and Integration

This is the main part of RFID middleware. It should be able to collect data from multiple disparate devices and ultimately be able to integrate that into other systems. EPC Global standards are helping on the data definition side and with providing schemas.

Data Structure and Data Association

Complexity arrives with attempt to integrate existing data structures. The need to associate information in a data hierarchy and roll small separate piece of information into higher levels of abstraction will be critical.

Data Filtering and Data Routing

The volumes of data generated by an EPC/RFID infrastructure will require significant data filtering to extract the most important information. The next challenge will be getting that information to the right person, place or system at the right time, so the appropriate action can be taken. Automation will be necessary or the system will fail.

Line Coordination and Process Control

Applying variable information in real-time on the production line will require autonomous, yet integrated line coordination and process control. Ensuring that uniquely programmed tags are placed on individual cases and pallets will require the control of conveyors, PLC`s, sensors, reject mechanisms, queuing and other components. Each line should run autonomously while being networked within a greater system to ensure data integrity.

Legend and Graphics Creation

Additional information on cases and pallets will be needed. For instance, at a minimum a human readable version of the EPC should be placed on cases and pallets, in the event of damage or removal. EPC barcodes are also likely.

Visibility and Reporting

The need for visibility and reporting will increase significantly. This will include data for quantitative and qualitative analysis, as well as for monitoring the health of the systems.

Track and Trace Applications

The end state intended for deploying this infrastructure is to be able to more detailed track and trace the position of goods in the supply chain. That information unlocks a whole host of new applications to enhance business operations and results. Immediate impact will be realized in:

- more accurate shipping,
- blocking products for quality purposes, and,
- efficient recall of products.

4. APPLICATION EXAMPLE

For the need of a big manufacturer of plastic tubes in Serbia, the Faculty of Technical Sciences from Novi Sad is developing a prototype RFID application. The goal is to automate the entrance of data in warehouse management system. Finished plastic tubes are collecting near the production line on dedicated pallet until the pallet is full (approximately 20 tubes). After that, the pallet is pushed outside the production hall where the forklift takes it and transports it to a faraway warehouse for finished goods.

The concept of RFID application is as follows. RFID read/write unit connected with PLC is positioned near the production line for plastic tubes. PLC is connected via the net-

working module with the factory Ethernet and appropriate information software and exchanges necessary data with factory software applications. Custom made middleware software retrieves data from the information system about the work order and product type that is being currently produced. After finishing the certain number of products (enough to fill up the pallet) the operator is entering through the appropriate HMI device into the PLC data about the number of finished tubes and confirms the work order and product type. PLC is generating time of data input and such data set sends:

- back to the information system as confirmation of partial order fulfillment, and,
- to the RFID unit which writes it to the tag.

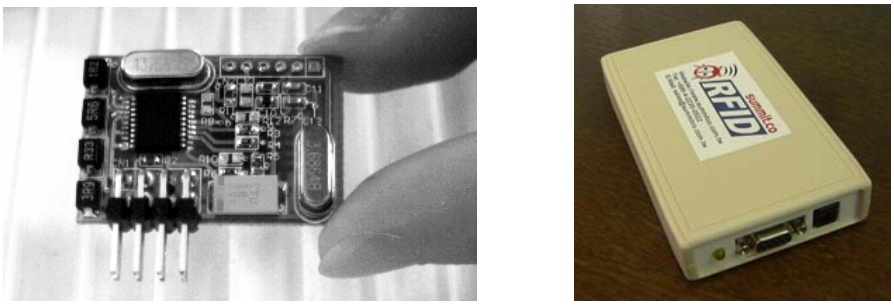
Tag is manually applied on one side of the pallet and taken away with the pallet. When the pallet is entering the finished goods storage it should pass by the RFID reader positioned on one side of the entrance door. Care has to be taken to position the right side of the pallet near the RFID reader. Reader is taking data from the tag and sends it to the PLC. This PLC is also connected via the networking module with the factory information software and sends received data from RFID reader, together with time of entrance, to the information system.

Chosen RFID read/write unit is ISO15693 Reader Module produced by Summit Automation Co. Ltd. from Taiwan and its features are shown in Table 3.

Table 3. Main features of applied RFID unit

Frequency :	13.56MHz
Tag :	ISO15693
Antenna :	50Ω (Ext.)
Interface :	3-wire (CMOS,TTL)
Baud-Rate :	19200, 8, n, 1 (default)
Power Supply :	5V / 200 mA (max)
Standby current :	5V / 300 uA
Operating Temperature:	0 ~ 60 °C
Operating Range:	6 cm (Avg.)
Mechanical Dimension:	30.0(L) * 28.0(W) * 8.7(H)mm

In Fig. 4 a selected RFID basic unit compared with human fingers is shown and completed as a product in a protective case and appropriate connections for information interchange and power supply.



a) b)

Fig. 4. Applied RFID Reader Shown as PCB (a) and Embedded in a Protective Case (b)

Selected tag for the start of application is ISO15693 tag in form of a credit card due to the ease of handling. Beside its own unit ID number that occupies two blocks of four bytes, the tag contains 62 blocks of four bytes that are able to receive customer data.

Data that are carried in tag memory are:

- product identification code,
- work order number,
- quantity of products on the pallet, and,
- time when pallet is filled up with products.

One block with four bytes is associated with each of given data; this leaves a lot of memory ready to receive further data if necessary. For example, possible future entries are: quality inspection data, operators name, etc.

The end result is that the same programmable logic controllers (PLCs) and industrial Ethernet network that manages factory information system also controls the RFID hardware and collects RFID data. A PLC module serves as the bridge between the two worlds, tying the data received from the RFID tags back into the PLCs for filtering and data handling. From there, the data goes through the Ethernet to a database where it can be shared with the rest of the enterprise.

In this way, the manufacturer got pallets with products designated with RFID tags and now it is possible to track products in time from production floor to warehouse entrance. Besides, it is possible to trace the product back to the production line and the operator who was in charge when the particular product was produced. If those data are linked with raw material data it is possible to locate the cause of a possible faulty product.

In this prototype application that is intended to meet the internal needs of manufacturer a reusable tag is applied. This means that before the pallet leaves the warehouse, the tag should be separated from the pallet and sent back to the production facility. If some of distributors should require designation of their products with RFID technology, in that case a printer/encoder that uses smart label stock supplied on rolls with RFID squiggle-tag inlays that are integrated into the label stock should be applied. Custom EPC middleware will pull data from the host ERP system and send it back to the label printer software and printer to generate the printed, coded labels. In that case, printed RFID labels will follow products to the final customer.

5. CONCLUSION

RFID integrated with MES and ERP could be used in varying scales to provide visibility into incoming row materials, work-in-progress, production sequencing, packaging, warehousing and final shipping to the next member in the supply chain. But, RFID is not a simple technology. Some of potential challenges to consider when implementing RFID solutions are as follows:

- when a large number of readers are installed across multiple facilities, configuration and management can be challenging,
- readers scan tag several times per second, which generates a high volume of raw data and processing of data can be difficult,
- in an enterprise with multiple facilities that are geographically distributed, it is difficult to manage data in real time,

- the attributes of each tagged product must be continually retrieved from a main database, a process that results in challenges for large-scale implementations, and,
- security and privacy challenges could have a significant impact on architecture.

In this paper we were trying to shed some light on the often used term of middleware. As one of the conclusions we can say that no single solution will cover the full range of functionality required from a single vendor. In a given application example, a mix of knowledge from ERP systems, databases, PLC programming, operators display programming, networking and RFID technology was necessary to address the whole problem.

We see the implementation of RFID technology as a catalyst for making process changes that improve business performance. Once the data is collected, it should be used to improve inventory tracking, automate many of quality control and inventory processes, and simplify data managing processes.

REFERENCES

1. Studebacker, P.: Plant to Enterprise, can you here me?, Plant Services Magazine, October 2005.
2. Hoske, M.: Analysis: Benefits of tighter GE Fanuc and SAP integration, Control Engineering, Reed Elsiever Inc., 2006.
3. Shaum, L.: Is RFID technology a real need?, Control Design Magazine, Putman Media, October 2006.
4. Šešlija, D., Tešić, Z.: Praćenje proizvoda u fazi proizvodnje pomoću RFID tehnologije, 8. Međunarodna konferencija UPRAVLJANJE KVALITETOM I POUZDANOŠĆU DQM-2005, Beograd, 15 – 16 jun 2005.
5. Warden, T.: The RFID road map: from "slap and ship" to high integrity data and the operational challenges ahead, MARKEM Corporation, 2004.
6. Warden, T.: The RFID Software Conundrum, Understanding Ambiguous "Middleware" and the Software Needed for Successful RFID Deployments, MARKEM Corporation, 2005.

RFID MIDLVER KAO SPOJ IZMEĐU PROIZVODNOG PROCESA I INFORMACIONOG SISTEMA PREDUZEĆA

Dragan Šešlija, Zdravko Tešić

Proizvodna preduzeća troše mnogo resursa na razumevanje gde se u realnom vremenu i u kom stanju proizvodnog procesa nalaze predmeti rada/proizvodi. Barkod čitači mogu da unesu podatke sa papira u računarske sisteme ali ne mogu da ih promene kada su jednom odštampani na nalepnici. U rezultatu toga, predmeti rada/proizvodi trebaju se ponovo označavati novim nalepnicama i potencijalna automatizacija je veoma ograničena. RFID tehologija pruža ekstenzivne mogućnosti za promene podataka o predmetima rada/proizvodima u realnom vremenu i unutar proces sa povećanom transparentnošću. Primenom RFID tehnologije tokom proizvodnog procesa, menadžeri mogu integrisati nove informacije dobijene od RFID uređaja. Izvršni Sistem Proizvodnje se može ažurirati kako bi isporučivao informacije u realnom vremenu radi boljeg upravljanja izvršavanjem proizvodnih operacija. U ovom radu učinjen je napor da se bolje razume RFID midlver kao ključna komponenta za uspešnu RFID primenu i integraciju u šire fabričke informacione sisteme kao ERP.

Ključne reči: *RFID midlver, Izvršni Sistem Proizvodnje, ERP.*