An Integrated RFID-Based B2B System for Supply Chain Logistics and Warehousing

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***Abstract*—**The need to track and trace objects in real time has determined numerous companies to adopt one of today's greatest contributory technologies, namely Radio-Frequency Identification (RFID). The paper examines the impact and the potential benefits generated by the integration of this technology in business-to-business (B2B) applications through a proposed RFID_B2B system. This system offers multiple performance levels for varying system and application needs, and can be readily personalized to meet current and future user demands. A proof of concept has been introduced to demonstrate the feasibility of an RFID_B2B application in a specific supply chain. A realistic business scenario has been taken into consideration to illustrate that RFID technology may enhance the operational efficiency in enterprise systems and even help numerous companies comply with the ever-growing demands of business customers. Furthermore, the authors maintain that RFID enables more integrated and collaborative B2B e-commerce solutions. The paper aims to increase awareness about the tremendous potential of integrating RFID technologies in B2B applications.

***Keywords*—**B2B, PDA, RFID, supply chain, tag

I. Introduction

RFID (Radio Frequency IDentification) technology is classified as a wireless Automatic Identification and Data Capture (AIDC) technology. RFID allows the identification, location, tracking and monitoring of various objects such as individual products or palleted goods [1]; real-time information about these objects can be easily obtained from the factory, through shipping [2] and warehousing, to the retail location [3]-[4]. Incorrect or outdated information used in invoices, bills of lading or purchase orders can result in product delivery errors and lost sales estimated at more than $50 billion annually [5]. But RFID technology can prevent these costly data inaccuracies [6].

The Internet has connected companies around the world and has changed how business is conducted across the world. Thus, due to economic globalization, enterprises need to carry out collaborative relationships with their suppliers and customers on the Internet [7]-[8]. E-commerce facilitates some forms of globalization; many in the world are able to compete in global markets regardless of languages, physical distance and national boundaries. E-commerce between businesses is defined as business to business (B2B). B2B exchange generally refers to any business transaction occurring between two separate business entities. This includes the exchange of products, services, or information between businesses rather than between businesses and consumers [9]-[10].

For many companies, providing real-time product availability to customers at minimal operation costs is an important factor that determines the success of their businesses. As one IBM study reveals, 70% of a typical distribution center's cost is represented by labor [10]. Tagging inventory upstream with RFID tags and automating this process via an integrated RFID_B2B solution achieve high levels of accuracy with better labor efficiencies and better velocity.

Following a short investigation of a business-to-business process, we maintain that RFID technology opens new opportunities for enterprise systems to operate efficiently and better comply with the demands of business customers. Furthermore, we also argue that RFID enables more integrated and more collaborative B2B e-commerce solutions [11]-[12].

II. System Architecture

Our research team has developed an RFID_B2B integrated system which combines the advantages of B2B with those of RFID technology and which presents itself as a viable solution for the problems raised by globalization. The software system deals with business relations between corporations, big companies and groups of companies, in order to optimize the flow of materials among them and the supply chain management inside every company. The RFID_B2B system could be tailored to the diverse needs of the companies and the different roles of employees in each company. The RFID_B2B system architecture is flexible and easily extensible.

To identify both parts and finite products, our system uses passive 13.56 MHz tags. Unique IDs are used to control and trace every part of a finite product. If this system is embraced by the entire supply chain management, final consumers will be able to follow the entire production chain of a finite product. And this is possible if the traceability information is memorized on each tag attached to some part of the final product.

The following case study scenario illustrates the many benefits that retailers can obtain through the implementation of RFID_B2B solutions: significant stock reductions, increased customer satisfaction and sales.

III. Case Study

Let us consider a medium-size production company called Company Prod and suppose that it assemblies PC components [13]. Company Prod uses RFID_B2B system in order to achieve increased performance and productivity in some main process: receive, ship, inventory. Various simplifications and assumptions are made to capture the

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essence of integrating RFID technology in a B2B process without making the case study unnecessarily complicated. Company Prod has an Internet connected PC network. Some of its employees use handheld personal computing devices, such as Pocket PC as an integral part of their job. Company Prod has three local storehouses and a fourth one in a different location. Each storehouse has two entry gates (a main and a secondary one) and two exit gates (also a main and a secondary one), which are supervised by several embedded devices with attached RFID readers; these devices will be called "gates". As RFID-tagged cases of components arrive from suppliers, gates read the tags and memorize the time they are coming into range and update immediately the components inventory. When components are taken out to be assembled with computers, inventory is reduced appropriately. The tag components products are read and tracked through the entire company with handheld mobile devices. Company Prod has more assembly stations. Every day, John picks up the computer components and drops them at the appropriate assembly station. As components leave the storage area, attached tags are read and the inventory is updated in real time. As John drops the components at each assembly station, tags are read, scripts are interpreted and the system verifies that the right type of components is dropped at the right assembly station. Michael works at one of the assembly stations. Once he assembles a computer, he creates a computer tag, associates the tags of the components to the tag of the computer and places this new tag on the computer case. Once Michael gets done a lot of computers, John moves the finished computers to the storage area. The system updates the finished products storage area inventory and the offered product web page. Through the B2B web platform a partner company can order products. When a partner places an order, one of two things could happen: 1) company Prod has the product in stock or 2) the ordered product wasn't in stock. If the first scenario is true, an invoice is created and is sent to the partner. If the second scenario is true, company Prod sends an email to his partner to notify about the estimated date of incoming delivery or cancels the order if it is no longer producing the ordered product. The partner whose order could not be fulfilled immediately could cancel the order, for example if it cannot accept the long delivery time.

At one of the exit gates, Peter consults the list of orders and is taking out products from the most prior order. As the product is coming into the range of the exit gate, the stock is modified consequently and the partner company is notified about the delivery.

Entry gates of the partner company register the product tags when they are coming into range. These data collection of precise and timely product information are immediately transferred to the system server. Within seconds the goods delivered are compared in detail with the goods ordered. Information regarding stock levels can then be obtained very quickly by authorized users.

The advantages with the RFID_B2B system is that all the items will be entered with specifications and prices, and it will give a real-time inventory control.
Once the user has selected the desired items and has added them to his shopping cart, he is ready to submit his order.

RFID_B2B system gives the user the flexibility to tailor his business to address the pricing variations he wants to support for his customers. Thus, this system supports personalized content and pricing for each customer. Different items, pricing and content can be displayed to different customers based on their price level, customer grouping, or purchase history.

This case study presents a simplistic view of a real-world scenario as the focus is on identifying the main benefits of the integrating RFID technology into B2B platform.

The system architecture is presented in
Fig. 1.

The integrated system comprises the following elements:

- an IBM-PC compatible computer which runs an OPC (OLE for Process Control) server with two main components: communication and data acquisition;
- an IBM-PC compatible computer which runs an OPC dedicated client; in fact one and the same computer may be used to run both the server and the dedicated client;
- a network comprising several gate devices; each gate has attached a low-cost RFID reader and processes the local data;
- PDA devices with attached RFID readers;
- an IBM-PC compatible computer which runs the local B2B server [14];
- an IBM-PC compatible computer which runs the central B2B server [14].

In this case study, we will consider three different complexity gates for each storehouse: Low Complexity Control Gates, described in [15] (which is referred as LCCGs), Medium Complexity Control Gates, described in [16], (which is referred as MCCGs) and High Complexity Control Gates, described in [17], (which is referred as HCCGs). The gates are connected to a RS485 network that will end on a PC with an RS485-RS232 connector [15]-[18]. In case the system uses an Ethernet connection, the MODBUS TCP/IP communication protocol is selected. The system is highly configurable and can be adapted to any demand.

Every storehouse has an Internet-connected PC running the OPC data server (OPC DAServer) [19]. The OPC client application may be installed on any computer connected to the company's network and may be used to watch data flow and even to modify the information from RFID tags and so on. At this level (company level), the application will be installed on a central system performing several operations such as the collection of storehouse data, the storage of the data in a database and the computation of reports about inputs and outputs or the stock level.

The basic information submitted by the control gates (read from the RFID tags) are imported by the OPC Data Server and saved into the central company database server using the Internet connection available. The software system we have devised enables the use of PDAs to read/write RFID tags associated to different products/parts.

Another feature of our software system is that a Web server may be easily installed in any company in order for the general public (future partners) or associated companies to gain access to certain information.

Let us consider the following example. Company Prod receives from a partner company named Distrib an order to

deliver a Desktop PC with the following configuration: All-In-One Asus K8U-X mainboard, Socket 754, AMD Athlon 64 3200+ processor, HDD Western Digital Caviar SE 200GB. Each PC component comes with an RFID tag that enables the unique identification of each product and contains specific product data. The components are registered when they leave the initial warehouse and then read when they enter the destination warehouse. The whole information is used to create the stock database; the same information may be employed for subsequent analysis or queries such as identifying transport times. Any system user may determine when and where an RFID tag was written/read and can trace all significant aspects related to a specific product. Stock related information is then sent to the main server of company Prod. Depending on the system's configuration, the partner companies registered into the system can access this information. Thus, an authorized partner always knows exactly how many computers and components are in the warehouse at Prod and is able to follow and react to changes in requirements in real-time.

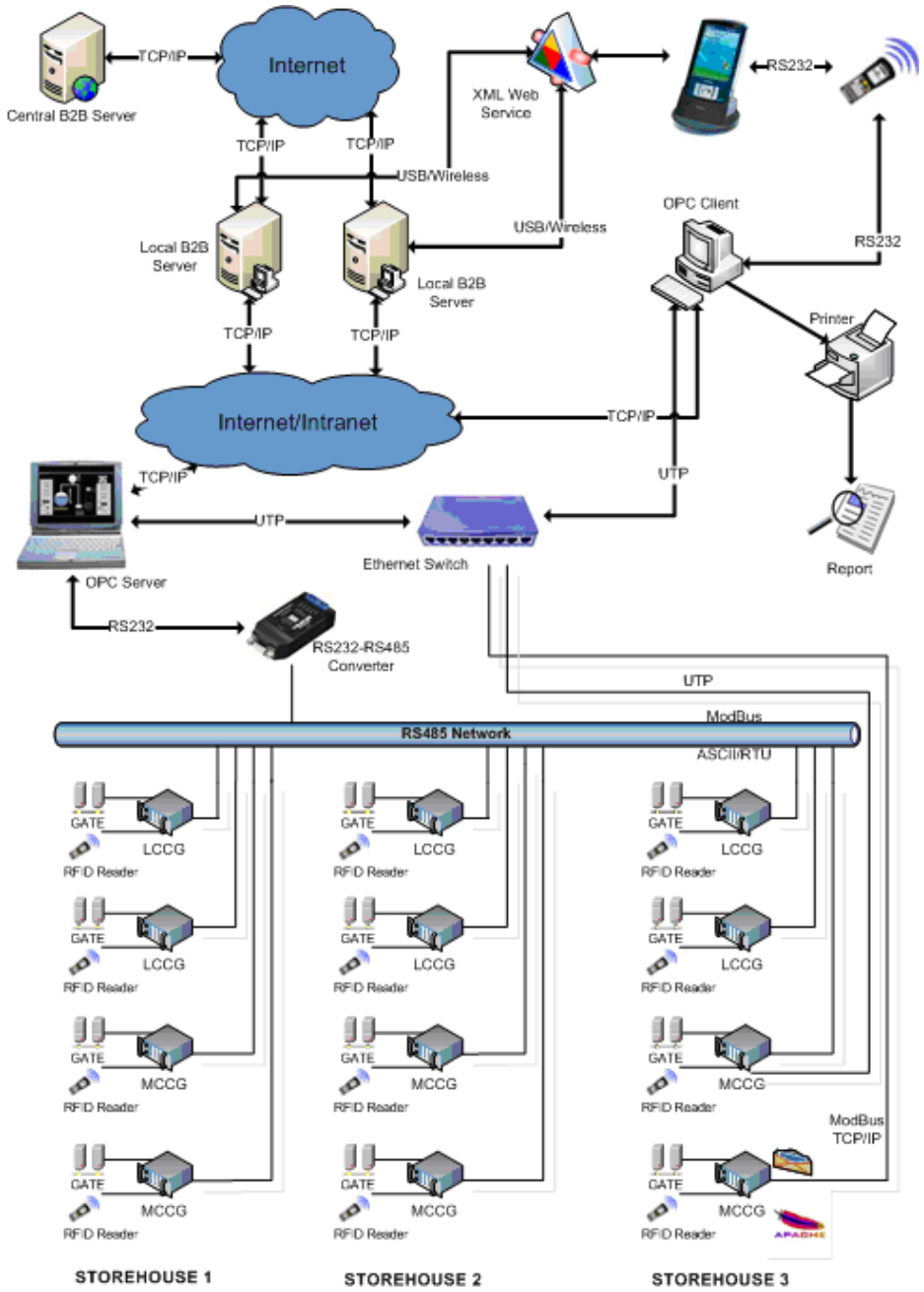

Fig. 1. The general architecture of the system

Our system provides a high degree of generality and enables its users to define their own templates, which describe the data format to be memorized on tags [20]. Script-enabled templates defined by the user [21] are used to trigger some local processing at the level of gates when a tag is read.

IV. System Functionality

RFID tags are attached to every component, spare part or final product manufactured by company Prod. Each tag will

pass through the RFID writing/reading area of at least three RFID readers functioning at the following levels:

1. First, there is the PC reader where the tag for the final product is initialized. After reading the information from each component tag, the reader writes the significant information on the main tag.
2. Second, there is the gate level where the main tag is read; the script is executed and, if necessary, the content of the tag is updated.
3. Third, there is the PDA level where the component data or final product data is verified. In other words, the data is processed in order to read/write component tags or final product tags.

In accordance with this organizing principle, templates have been devised for each component and final product at the PC level. Similarly, scripts may be created to be compiled to byte-code and written to tags; each script is executed when a tag is read at any level (PC/PDA/gate) (Fig. 2). For instance, a script for final product tags may be defined to be executed at the level of the distribution company. If the product happens to be rejected (PROD_ACCEPTED = 0), then it should never be intercepted at any gates except for the entry/exit ones. The considered script (Fig. 2) will generate a "forbidden gate" event when that product is detected anywhere inside the company (gates, PDA, etc.).

```
#DEFINE PERMITTED_GATE 0x00 BYTE
//permitted only on entry/exit gate
#DEFINE EVENT_FORBIDDEN_GATE 0x55 BYTE
//event for a forbidden gate (usually at
// gate level)
#DEFINE ACCEPTED 0x0A BYTE
//field 10 on tag (PROD_ACCEPTED)
#DEFINE GATE_COUNT_FIELD 0x00 BYTE
//we will define a field that will
// memorize the number of gates
// that the product passed
#DEFINE GATE_MAX_COUNT 0x0F BYTE
//10 gates maximum
#DEFINE SEND_MAX_COUNT_REACHED 0x00
  BYTE
//we are defining the event
INC(GATE_COUNT_FIELD)
//the number of passé gates is incremented
IF(GATE_COUNT_FIELD==GATE_MAX_COUNT)
  SEND_MAX_COUNT_REACHED
//if the maximum number of gates reached,
// then send an event
IF(ACCEPTED == 1) STOP
//if accepted then we are not triggering
// any event
IF(GATE!=PERMITTED_GATE)
  EVENT_FORBIDDEN_GATE
//if wrong gate, we are generating
// an event
STOP
```

When a template is created, the establishment of visual groups is advisable for a better organization of all fields considered; in this way, the visualization of PDA data is correct and logical. The creation of a new template requires the activation of the pre-visualization field and the implementation of the correct and desired configuration (Fig. 3). The data to be displayed at the PDA level is easy to be visualized (Fig. 4).

Through the use of user-defined templates and scripts, the presented system can be easily adapted to meet future needs of the user just as well as it meets today's needs. The created templates are used in order to write some product tags with specific information. This feature enables reading of the tag content for authorized users only. Hence, it is impossible to identify the contents of the tag without the corresponding template. The desired information is recorded both on database and tags (Fig. 5). Product information is constantly updated in the stock database and the web-server database. Users can create a succession of personalized reports using the report editor embedded in our system (

Fig. 6); in fact, specific SQL statements are generated and saved into text files for further usage. The data requested for display may be easily exported in Excel files.

All created templates and tags can be exported from the database into an XML file or imported from an XML file into the database. Moreover, the XML file may be mailed, upon request, to a business partner.

Manual data handling was a problem that affected the supply chain, product traceability and B2B processes. To improve data accuracy and increase mobility the RFID_B2B system allows the use of mobile devices. The mobile application enables the communication with other systems and allows the connection with higher enterprise levels. The software application that runs on mobile devices and that is integrated into the complex RFID_B2B system perform the following functions:

- read and write RFID tags;
- work in stand-alone mode (independently of the main servers);
- store huge data;
- integrate and exchange information with complex RFID_B2B systems and other PDA mobile devices;
- ensure maximum security;
- employ a multi-user and user-friendly interface.

A registered mobile user can view the tag templates stored on the PDA and can update tag information or create new tag records according to his privileges on database. He can also manage the templates and tags databases. The mobile application security prevents unauthorized users from viewing or updating the databases. Using mobile application integrated in the RFID_B2B system, the authenticated user can read the stored information into tags and can update the databases from the PDA. He can also write and update the tags with database records according to the own settings. Within the mobile application the authenticated user transfers the records within database tables from PC to PDA and in inverse order, for the update of the database from the PC and from the PDA. More data in the database leads to increased data transfer time. But the RFID_B2B system allows a total or a partial transfer of records between PC and mobile device. The partial transfer assumes that only changes in data are transferred. The authenticated user can also select the desired records to transfer. With the mobile component of the RFID_B2B system encrypted data can be safely transferred across any

kind of Internet-connected network. He can also manage the system registered users, enabling users' visualization, adding or deletion of certain users, profile modification, etc. Only the user with the specific system privileges can administrate the events database. The mobile application supports multi-user configuration to meet the requirements. Thus each registered user can set his own configuration.

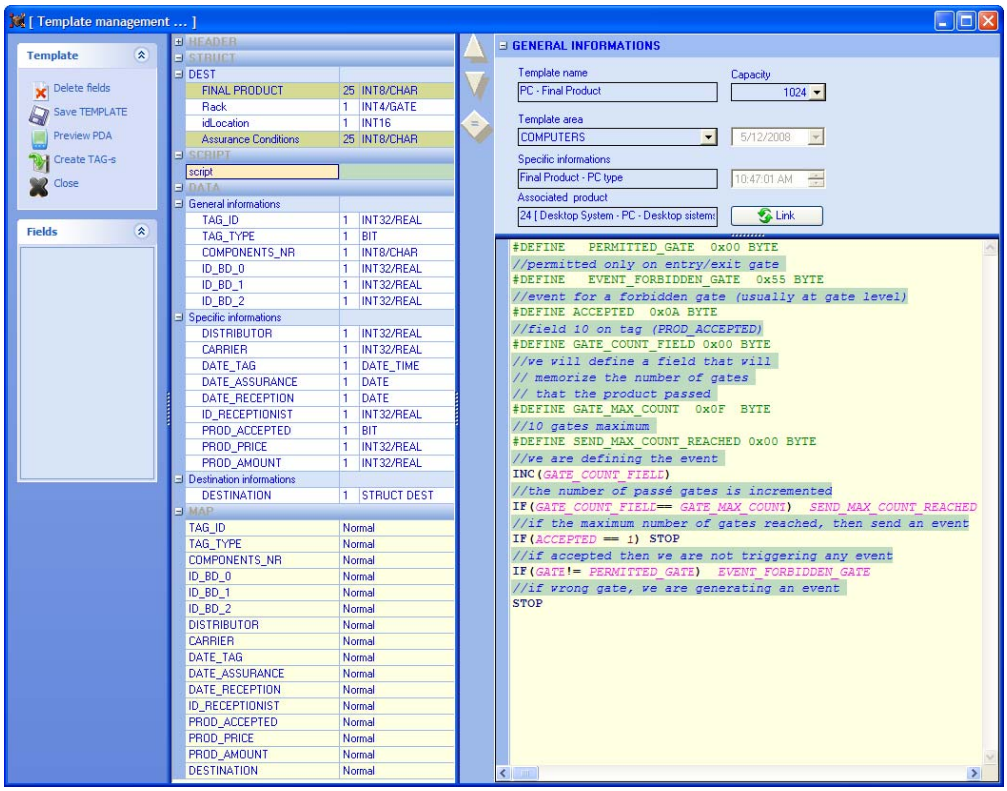

Fig. 2. The script– template PC – final product window

Fig. 3. PC Component. PDA Preview, first and second visual zone

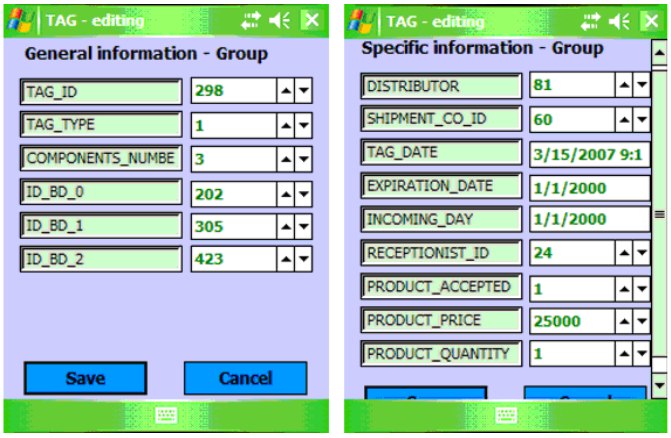

Fig. 4. First and second visual zone on PDA

At the gate level, when a tag is detected in the proximity of an RFID reader, the entire content of the tag is read. Then, the authenticity of the tag is verified and if there are some problems an alarm/ event will be generated. If the tag is correctly authenticated, then the gate will start processing the data requested by the central PC or executing the local script from the tag. Consequently, the gate will read the entire content of the tag and, if necessary, will write new data or just update certain fields. The data read from the tag at the gate level will be sent to the central PC using the communication component that is running there and therefore written into the central database.

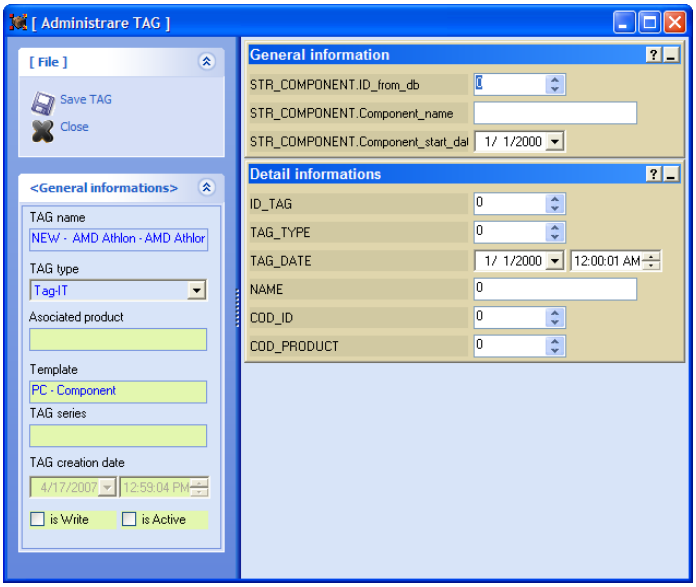

Fig. 5. The window for the motherboard tag

All events generated by the gates are recorded in their internal memory and in the central PC database. At the same time, Web interface allows the access to several advanced gates. Using the Web page menu, any authenticated user can consult various reports on the traceability of tags, and can establish the events to be displayed on the Web page (for example, authorized tags, unauthorized tags, modified fields, memorizing the tag content into the gate memory, etc.).

Using a standard Web interface, the RFID_B2B system facilitates information exchange and communication between a company and its partners. Each company can have a local Web server connected to the central Web server. The establishment of business partnerships and the placement of orders are supported by the system included in our software platform. This system manages the communication process with business partners including: purchase order, change orders, purchase order confirmations, vendor managed inventory (VMI) visibility etc. The Web platform accepts both registered and unregistered users. Besides accepting both registered and unregistered users, the Web platform supports the easy administration and organization of company data, partners, and products (Fig. 7). For example, the product page displays the product name, the product image, the corresponding quantity and the product price. If the company offers a new product or the stock of one displayed product is changed, the Web page is immediately refreshed without any intervention of the user. The selection of a product will display the product details section (Fig. 7) and offer the possibility of changing the editable fields. For example the stock (Quantity) cannot be changed in this section. It is updated automatically as the products come into or leave the company or as soon as they are coming

from the assembly or production area. The products are organized in categories that can be dynamically changed. Operations like creating new categories, renaming one of the existing or moving products from one category to another can be easily performed through the web interface. For each product the authorized users can add specific information like: weight, volume, resolution (for example for a monitor), or the memory capacity (for example for a laptop) for a better description of them. These fields can vary for each product from 0 to as much as necessary. They are displayed also to registered or unregistered users that visit the company site and enhance the decision of choosing one product or another.

The admin user can create local users and groups of users, with corresponding read/write rights as well as other specific rights. Also he can record some other kind of data such as partner companies and their profiles and some other useful information on business partnerships. Some user categories are entitled to officially decide upon the products to be sold by the company and to verify stocks. This data can be managed and monitored by company-registered users and delivered to end users. Business-to-business customers can place orders using a real-time Web interface, check product availability and inventory status, get sales information, etc. The software platform is flexible enough to allow all authorized users to visualize a whole range of reports and data.

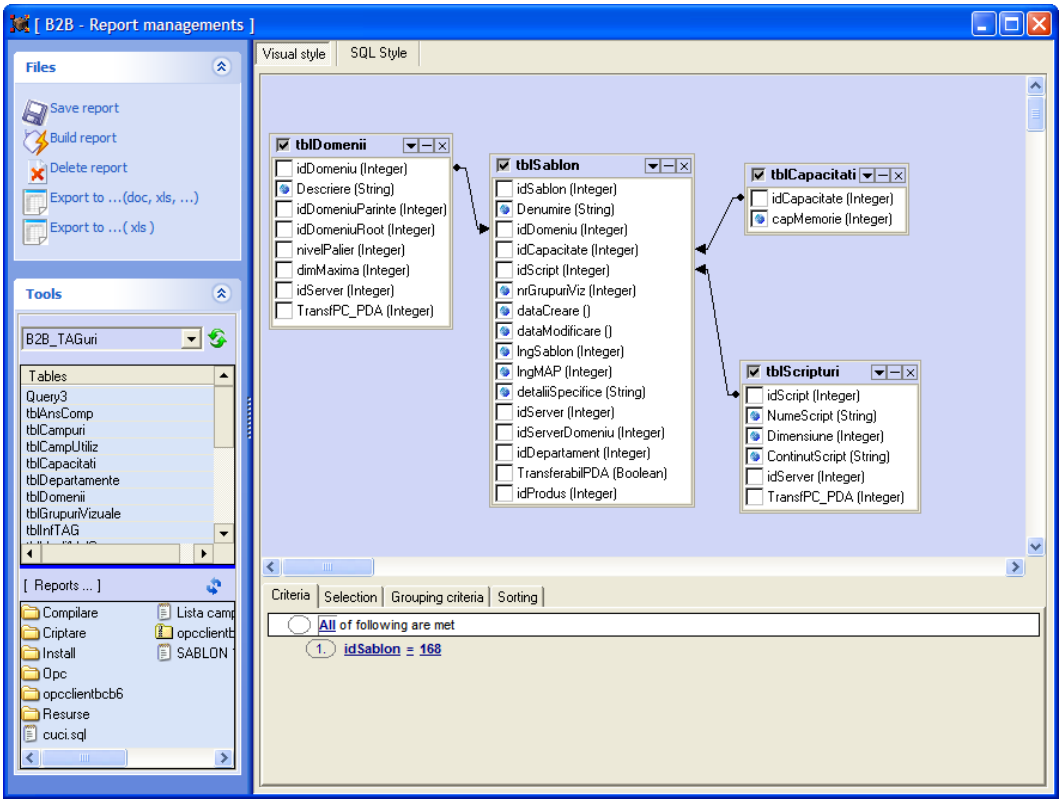

Fig. 6. Report editor

The software platform enhances the establishment of more rapid transactions and simplifies the partnership protocol between two or more companies. Businesses must vary their offerings to match costumers' price expectations. Product promotions are a key vehicle in retail, especially for consumer packaged goods companies. A considerable amount of money is often spent on each promotion. Through the power of RFID_B2B platform, retailers and manufacturers can easily gain the visibility and intelligence required to monitor and analyze the rate of promotion success. The authorized users can specify up to four types of discount: one product for a company, all products for a company, one product for all companies and all products for all companies. These types represent all the possibilities that a company can use for promoting their products or to improve the partnership with some companies. The changes are visible when the specified date from configuration is reached. From high profile promotions that involve special manufacturer-sponsored displays to retailer-created programs that promote new item, RFID automates the huge collection of data required to maximize the sales and revenue opportunities of promotional programs. Furthermore, the Web platform was carefully designed to help the company look for potential partners, to maintain and develop already existing business partnerships without ignoring new possibilities of expansion and development. The user end interface is simple and intuitive, but fast and robust.

V. System Benefits

Integrating RFID technology into a Web B2B software system has resulted into a complex platform with major advantages against the facilities offered by classic B2B sites:

- a better interaction between partners, and the development of services aimed at enhancing client loyalty and ensuring the rise of sales;

- greater visibility through permanent presence of companies in a virtual market capable of enhancing the development of registered companies;
- the organization of exhibitions and promotion campaigns for products or services in a permanent virtual show-room which facilitates market access;
- a more accurate evaluation of market demands, better management of stocks;
- an error-free environment by using electronic data;
- closely inventory and availability management;
- reducing manual supply chain processes and transaction costs;
- the removal of intermediary agents/companies;
- increasing the amount and type of information that a company share with its partners;
- a faster access to market information and the accumulation of considerable business knowledge among the participants in the virtual market, both qualitatively and quantitatively.

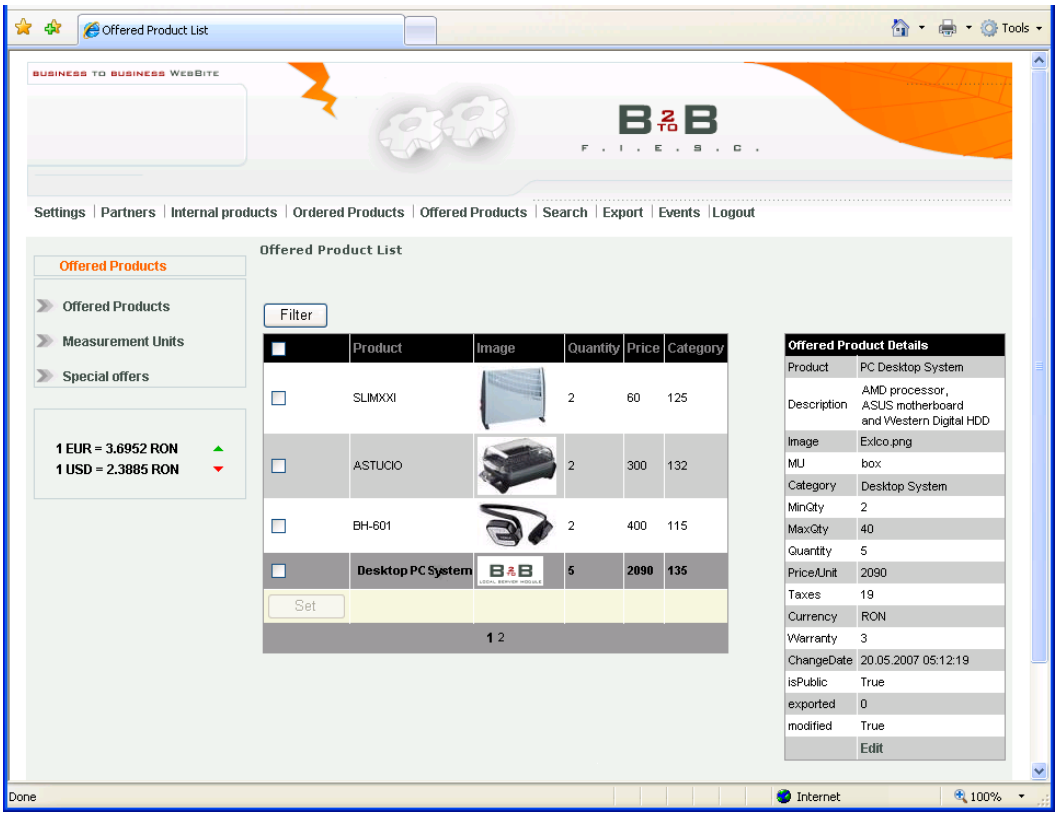

Fig. 7. Product page

Unauthorized readout of the RFID tag content has raised privacy concerns from different B2B participants (retailers, consumers). The RFID_B2B system provides counter measures which enhance B2B partners' privacy. Thus, the developed template framework represents a simple and efficient answer to prevent unauthorized reading of tag data. This solution has an almost limitless potential for product applications across a wide range of industries including retail, automotive, healthcare and more.

VI. Future Improvements

With the growing number of B2B sites available through Internet, a useful addition to the RFID_B2B system would be an intelligent software agent for information gathering. The agent will be able to perform semantic query optimization and to offer data mining facilities. It will dynamically plan for alternative information source when a source or a B2B site goes down. This agent will organize the results and display them in an easily interpreted manner to the user.

A useful feature would be a special section that enhances the management of production planning to ensure good deliveries and productive efficiencies.

VII. Conclusion

In a global market where change is continuous, companies require tools that allow them to respond quickly to new opportunities. The presented RFID_B2B system can be considered as a viable solution for potential problems raised by globalization process, contributing to a significantly more efficient business process. We have chosen to analyze a simple scenario that does show the potential of the RFID technology in a B2B platform. With this system companies achieve lowering inventory costs, improve operational efficiencies and gain visibility on the market. Because different data users can impose different requirements the developed system is flexible and scalable. The RFID_B2B system allows users to exchange precise information amongst B2B transactions, to automate routine purchase-order transactions, to reduce the cycle time for purchase-order placement, to reduce errors etc. A company can quickly add new partners and can choose to share more real-time information with its partners.

We believe that integrating RFID technologies in B2B

applications develop new opportunities for business in the near future.

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