Zoran Kalinić[1)]
Slavko Arsovski[2)]
Zora Arsovski[1)]
Vladimir Ranković[1)]
Igor Milanović[1)]
Dragana Rejman-Petrović[1)]

1) Faculty of Economics, University of Kragujevac, mail: {zkalinic, zora, vladar, djidji, rejman}@kg.ac.rs

2) Faculty of Mechanical Engineering, University of Kragujevac, mail: cqm@kg.ac.rs

MOBILE SUPPLY CHAIN MANAGEMENT – KEY TECHNOLOGIES AND APPLICATIONS

Abstract: *Modern supply chain management is often based on extensive usage of information-communication technologies. In order to improve the quality of service and goods and provide more efficient work and better communication and coordination among all participants in the supply chain, in the recent years a special emphasis was put on the implementation of mobile devices and wireless communication systems. In this paper, the key mobile and wireless technologies used in modern mobile supply chain management are presented. A special emphasis is placed on the development of information systems based on mobile web technology, which enables identification of accessing mobile device and information and content adaptation for optimal view i.e. presentation adapted to the characteristics and capabilities of the device. Also, the main characteristics and applications of mobile supply chain management are presented.*
Keywords: *mobile device, supply chain management, RFID, mobile web*

1. INTRODUCTION

In recent years there has been intensive development of information and communication technologies, especially wireless communications and mobile devices. It is obvious that the wireless communication and Internet access are the basis for future development in communications, which is one of the most profitable and most expanding fields of technology [7].

The most obvious advantage of using modern wireless and mobile technologies in supply chain management is in providing highly efficient, fast and accurate means of collecting and sharing information and data on the movement of goods and other important events. These features make it easier to control and monitor work activities and provide updated information on the status process, which enables a company to establish and maintain complex adaptive supply chain network.

2. KEY MOBILE AND WIRELESS TECHNOLOGIES USED IN SUPPLY CHAIN MANAGEMENT

Mobile devices

Mobile technology is now one of the most dynamic, pervasive, and fastest developing technology today. The most frequently used mobile devices are mobile phones, PDAs and smart phones [8].

According to ITU, the UN agency for information and communication technologies [6], by the end of 2010, there was over 5.3 billion mobile phones in the

world (estimated population of our planet is about 7 billion people), and only in the year 2010 there were produced and sold over 1.6 billion mobile phones [5], which makes mobile phones far the most frequent technological device in the world ever.

PDAs (Personal Digital Assistants, also known as palmtop and handheld) are pocket computing devices. They were originally introduced as an electronic version of a pocket reminder (PIM - Personal Information Manager), or to store and administer address books, calendars, daily work, a reminder of the planned duties, personal data and notes, etc. They belonged to a higher class of devices, by its characteristics (almost all PDAs have touch screens) and the price, so it never achieved the popularity and spread of mobile phones. In recent years the market for personal PDAs in a decline. However, considering that mobile devices must be sufficiently robust and resistant, to withstand tough working conditions for example in production or in the field (drops, dust, rain, etc..), and that classic mobile phones often can not cope with work in these conditions, there is still a significant usage of industrial PDAs, specialized for such conditions.

It's a natural tendency in recent years that these two types of devices are converging, thus resulting hybrid devices (that have all the good characteristics of both types: they have potential for voice communication over a mobile networks, own high level operating system and the ability to install new software applications, powerful computing features of PDA devices, connectivity to wireless LAN, etc) called smart phones.

Data transfer standards and technologies

Bluetooth

Today, Bluetooth is considered as de facto main standard for short distance data transmission. Its range, depending on the class of devices, is usually up to 10 meters. The maximum data rate of current standards in use (2.0 and 2.1 + ERD) is 3 Mbit/s, but achievable is about 2.1 Mbit/s. Since it does not require optical visibility, Bluetooth enables connection of multiple devices, even in different rooms, allowing the creation of WPAN (Wireless Personal Area Network).

The disadvantages are some difficulties to connect and procedures of recognition, pairing and setting up links, as well as some aspects of security (thief of data from mobile devices via Bluetooth).

Mobile networks

Wider use of mobile phones began by intro-duction of second generation (2G) of mobile phones, because phones of first generation (1G), beside high price, had the analog transmission system, large size and power consumption.

2G networks were developed primarily for voice communication and relatively slow data transfer (up to 9.6 kbit/s). **2.5G technology** introducted new protocols (e.g. GPRS - General Packet Radio Service), with much higher data rates (56-114 kbit/s), which enabled the introduction and use of new services such as WAP access, MMS, email and web. **2.75G technology** is based on EDGE (Enhanced Data Rates for GSM Evolution) technology. Thanks to the data transfer rates up to 236.8 kbit/s, users are provided a relatively fast Internet access and many digital mobile telephony services.

3G networks enable simultaneous voice and data transfers, at higher speeds (e.g. 384 kbit/s) and level of security than the previous generations. UMTS (Universal Mobile Telecommunication System), is one of the most common standard for 3G networks. It requires new network of base stations and different operating frequency. Since 2006. UMTS networks are upgraded by the introduction of HSDPA (High Speed Downlink Packet Access), often referred as 3.5G

technology, with a maximum data rates of 21 Mbit/s.

Wireless networks

The rapid development of technology, miniaturization and falling prices of components, enabled that Wireless Local Area Network (WLAN) is no longer a privilege of only laptops, but also a feature of many modern smart phones (by end of 2009, 84% of them [1]). Today, the most commonly used wireless networks are Wi-Fi (short for Wireless Fidelity), based on IEEE 802.11 standards group, which work based on the existence of access points (hot spots) - the router that covers a specific area and allows all devices in it connection and network access. The range of such devices is usually around 30 meters indoors and 100 meters outdoors.

Modern mobile devices today often use IEEE 802.11b or 802.11g standard, with maximum theoretical data transfer rates of 11 Mbit/s and 54 Mbit/s, respectively. The latest IEEE 802.11n standard, published in October 2009, thanks to the transmission system with multiple antennas, will allow data rates up to 600 Mbit/s, better reliability of transmission and the greater distance (two times the range of networks with previous standards).

Currently, 3G networks are considered as optimal solution for data transmission via mobile devices. 2G and 2.5G networks give very good coverage (up to 100% of the territory), but not the capacity, i.e. data transfer rate. WiFi provides high capacity, but still not high geographical coverage. 3G networks, as a compromise, now provide slightly less coverage of 2.5 G networks (but much better than WiFi), but much higher data rates, that allows the transmission of video signals, g internet access, lower costs, longer battery life, increased functionality, “always on-line” status, GPS, etc.

GPS

A large number of modern mobile devices, thanks to falling prices and diminishing size, also has a built-in GPS receiver. (by the end of 2009, 83% of smart phones had it [1]). GPS (Global Positioning System) is a global satellite navigation system, which consists of satellites (24 satellites distributed in six orbital planes) deployed in orbit of the Earth, which send a radio signal to the Earth's surface. It was originally developed for the U.S. Department of Defense, but later became open to all users and applications, free of charge.

GPS receivers, based on the signals from the satellites, determine its position and altitude, latitude and longitude, as well as direction and speed, anywhere on the planet, day and night, in all weather conditions. The accuracy is about 10 meters, but this method can not be used indoors, since it requires optical satellite visibility.

GPS in mobile devices today offers a range of features and useful applications, primarily to navigate on the unfamiliar terrain (software with digital maps of cities and roads), and tracking of vehicles and cargo.

Mobile web

Mobile internet, i.e. mobile web is the use of the Internet by mobile devices and has its specifics. Mobile web sites are those sites that are designed specifically for mobile devices, and should be distinguished from the web sites designed for viewing by PC, accessed by mobile browser. Because of the limitations of mobile devices, especially in terms of screen size and memory speed and data transfer rates, it is often necessary to create these special sites, so that users who access from mobile devices have an optimal or at least a decent quality of work.

Although the mobile web site is relatively easy to create, there is a problem of a uniform view on different platforms.

In the past, the mobile web was based on the WAP standard, which is now obsolete and today standards based on the combination of XML and HTML (XHTML) are used. Using the mobile web is growing in all markets in the world [4]. Almost all modern mobile devices have built-in web browser, which along with the reduced prices of data transfer via mobile networks and the growth of number of Wi-Fi points, promises that the mobile web will soon become one of the most important channels for information distribution.

RFID

RFID (Radio Frequency Identification) is a technology which uses radio waves to communicate and exchange data between a reader and tags attached to an object, for purposes of identification and tracking.

RFID tags are being developed to replace bar codes. Bar codes have a number of limitations: they require optical visibility with scanner, are printed on paper and can easily be tear, soil or lose, only identify the manufacturer and product, but not individual items, etc.

Each RFID tag has a unique identifier, assigned to a particular product or packaging. Depending on whether they have their own power supply (battery) or not, tags are divided into active (with own power supply) and passive. Reader through the electromagnetic (radio) waves reads data from the tag and forwards them to the system for data exchange and management for further processing. Active RFID tag reading range is 10-100 m, and for passive ones is 10 mm to 5 m. Tags are becoming smaller and smaller (Hitachi has made RFID chip measuring 0,05 x 0,05 mm, which can store 38-digit number [10]).

Compared with its predecessor, the bar code technology, RFID has the following advantages [9]:

- does not require optical visibility for reading,
- can store a larger amount of data than bar code (e.g. it is possible to keep the information on each individual product, not just a class of type)
- smaller size, come in many forms and shapes,
- much safer. Given that the electronic nature, may use content protection code, so it's not easy to read and forge the content
- data is stored in the RFID tag can be changed or added,
- resistant for work in dangerous environments,
- a large number of RFID tags can be read almost instantaneously,
- rapid response system,
- cost reduction (in the long run), and so on.

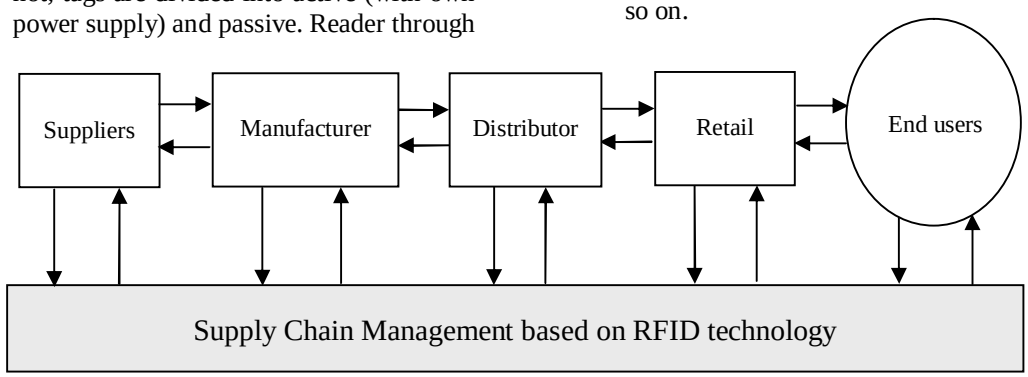

Figure 1. The structure of RFID-based Supply Chain

RFID technology has increasingly been applied in different areas of the economy and parts of the supply chain, such as: the production, receipt and issue of goods, transportation, distribution, warehouse operations, retail, etc. Some of the world largest retailers (e.g. Wal-Mart in the U.S., Tesco in the UK) and government institutions (US Ministry of Defense) bind all of its suppliers to introduce RFID technology.
The structure of the supply chain based on RFID technology is shown in Figure 1 [9].

3. MOBILE SUPPLY CHAIN MANAGEMENT

Mobile supply chain management (mSCM) is defined as the use of mobile devices and applications to assist in the efficient and effective management of various activities in modern supply chains, contributing to better company's operations by reducing costs, faster response system and achieving competitive advantage [2]. The most obvious advantage of using wireless and mobile technologies in the management of modern supply chains is that companies are now able to provide customer service no matter where they are and at a time that best suits them [2]. In addition, mobile applications for supply chain management can be used to improve the business processes of different business functions by ensuring efficient flow and exchange of information and goods between the various supply chain activities, from product concept, its design, manufacturing, sales, customer service, and all by the end of its life cycle, i.e. use.

Mobile systems for supply chain management integrate software applications with mobile devices (e.g. mobile phones, PDAs, pocket computers, etc.), in order to provide flexibility for users to work in the wireless computing environment from any location [2] (e.g. shop or warehouse, using mobile devices and possibly other wireless units (e.g. RFID readers)). Mobile devices connect to the company server via a wireless infrastructure (mobile network or WiFi-WLAN), which enables data and information exchange between different functions within a company and along the supply chain. In this way, a software application for mobile supply chain management enables intra-company and inter-company business systems, enabling participants in the supply chain to realize business activities such as online transactions, share and exchange of updated information, providing customer service, logistics and transport management, warehouse management, and so on.

Transactions that are entered through mobile applications can be processed immediately or asynchronously, or when the customer voluntarily submits it to the processing center.

On the market today there are several commercial solutions for mobile supply chain management, developed by the famous companies in the field of software and business information systems: SAP, Oracle, Motorola, Guotong Supply Chain Corporation, etc, applicable on supply, production control, warehouse management, transportation, etc. [12].

Application areas

Information – Information management i.e. fast and efficient reception, transfer and exchange of information is one of the key aspects of mobile supply chain management. Except for reception, mobile devices are used to collect, generate and distribute information to the others, including updating information on central inf. system.

Mobile production - In combination with scanning of bar codes or RFID tags, data entry using mobile applications allows more efficient use of time and the possibility of validation and correction in

real time [12, 2, 9]. Production workers can use mobile devices to read operating instructions, anywhere within the factory i.e. at their workplace/ environment. Also, production data and task reports can be collected.

Mobile inventory management - Accurate and efficient inventory management, based on the solutions with bar codes or RFID tags, is used to track the level of the stocks of those products that are critical for the company. In this way, companies can reduce the problems of duplication or lack of entries, and enable people to know exactly where some item is [9, 12].

Mobile sale - Using mobile systems for supply chain management, retailers can increase sales by providing the right amount of right products at the right place at the right time. The system improves customer satisfaction by informing them about the status of their orders and reducing the probability of delays or incomplete orders [12]. The system also improves customer service and the ability to quickly respond to customer needs changes, by passing information about the new requirements throughout the supply chain and by possibility of using mobile devices to serve customers on site.

Tracking goods in supply chains – By using GPS systems, mobile devices and networks, now is possible to monitor the progress of each transport vehicle in real time efficiently, and thus to know exactly its position and time of arrival at the final destination, and the type and quantity of goods carried by transporter, thus opening to possibilities of transport optimization and lowering the costs.

4. CONTENT ADAPTATION BASED ON DEVICE CAPABILITIES

As already stated, web technology is the basis for the use of modern information technologies in supply chains, including mobile systems. Web access from mobile devices has its own characteristics, and very rarely a good solution is to use the same web site for access from computers and mobile devices. Very often good approach is to make a special site, optimized for mobile access.

With a huge number of mobile devices on the market (it is estimated that today there are over 3,000 different models of mobile devices, with nearly 30 different web browsers [3]), and their different characteristics, it is impossible to make a mobile web site that will equally suit every device. In order to optimize the display of the content on different mobile devices, it is necessary to adapt the content according to its capabilities. The adaptation process is divided into two steps: device detection/identification and the content adaptation i.e. its dynamic generation. Both of these steps are performed on the server because, compared to the server, the mobile device has limited resources and capabilities. For the same reason, usually mobile device, as client side, is used just for presentation i.e. display of pre-prepared content.

Device identification

When a mobile device i.e. its web browser attempts to open a web page, it sends an HTTP request to the server, asking for a file (including HTML files) or document. On the basis of this request sometimes is possible to determine from which mobile device the request is sent, but the basic problem is that it does not have a standard structure. In order to resolve this problem, device libraries are used. Library devices are off-line databases or online services that, based on HTTP request sent from accesing device, detect it and give back its features and characteristics [3].

One of the most famous device library is WURFL (Wireless Universal Resource File). This is an open-source repository, created and maintained by Luca Passani (and members of the community), and is

the largest and one of the most active open source projects in the mobile world [3]. WURFL is actually an XML configuration file which contains information about the capabilities and characteristics of most mobile devices [4]. Another famous example is DeviceAtlas, device library launched in February 2008, by the company dotMobi. This is a commercial product, with many partners and data providers. According to the owner, this is not only the largest but most accurate device database on the market [3].

Content adaptation

Based on the identified characteristics of the device, it is possible to adapt content, so it is displayed optimally according to device capabilities. This adaptation is performed dynamically on the server side and to mobile device fully customized pages are passed. Adaptation involves adjusting the size of text and images to screen size and resolution, presentation of only those types and multimedia formats supported by the device, and so on. This avoids unnecessary download of unsupported multimedia content, large images, scripts which can not be executed, etc, giving users a better display quality and work while saving time and money.

Figure 2. Identification of mobile device and its characteristics (a), image size optimization, according to device screen size and resolution (b) and (c)

At Faculty of Economics, University of Kragujevac, web applications and systems for mobile education are being developed for several years [8]. Adapted version of the system can be used in the process of information distribution and exchange within the mobile supply chain. The system is based on web technology, and all information and data are stored in a MySQL database. PHP, one of the most widely used tools for the design of dynamic server-oriented web applications, was used as a programming language for necessary functions and scripts. In order to each client receive information adapted to the capabilities of its mobile devices, WURFL mobile device library [11] was used for the identification of accessing device and its characteristics. Figure 2 shows the simulated access to the system (simulation was done on a mobile device emulator http://www.mobilephoneemulator.com/) and some of the characteristics of the device.

Based on the identified characteristics, the adaptation of content, especially optimization of image size and selection of supported media content, is done. Figure 2 (b) and (c) also shows the same image (the

original size 720x540px), but optimized for different resolutions of accessing device: b) Samsung i5700 GT Galaxy Spica (320x480px) and c) RIM BlackBerry 8900 Curve (480x360px). This ensures that every participant in the supply chain has the optimal information presentation, in accordance with the characteristics and capabilities of its mobile device.

5. CONCLUSION

This paper presents the most important mobile and wireless technologies that are used in supply chain management systems and the most important fields of application. Most modern mobile systems for supply chain management are based on web technology. In order to provide each mobile user with optimized content presentation, it is necessary to identify the accessing device and dynamically adapt the content. The paper describes this process and the results of test application developed for Faculty of Economics, University of Kragujevac.

In further research, the emphasis will be on further development and adaptation of mobile applications for supply chain management, primarily in terms of efficient data collection process and transfer to the central system, to make them available to other participants in the chain.

REFERENCES:

[1] Canalys, (2010), Majority of smart phones now have touch screens, www.canalys.com/ pr/2010/r2010021.html, [last acc. 28.04.10]
[2] Eng, T-Z., (2006), Mobile supply chain management: Challenges for implementation, Technovation, 26 (2006), pp. 682-686
[3] Firtman M., (2010), Programming the Mobile Web, O'Reilly, ISBN: 978-0-596-80778-8
[4] Fling B., (2009), Mobile Design and Deve-lopment, O'Reilly, ISBN: 978-0-596-15544-5
[5] Gartner, (2011), Gartner Says Worldwide Mobile Device Sales to End Users Reached 1.6 Billion Units in 2010; www.gartner.com/ it/page.jsp?id=1543014 [last acces. 24.02.11]
[6] ITU, (2010), The world in 2010: Facts and Figures, www.itu.int/ITU-D/ict/material/ FactsFigures2010.pdf, [last acc. 28.01.11]
[7] Kalinić Z., Arsovski S., (2009), "Mobile Learning – Quality standards, Requirements and Constraints", International Journal for Quality Research, Vol. 3, No 1, p 7-17, ISSN 1800 – 6450
[8] Kalinić Z., Arsovski S., Arsovski Z., Milanović I., Ranković V., (2010), "The application of mobile technologies in the processes of communication and information delivery to the students for the improvement of education process quality", 4th IQC, May 2010, Kragujevac, Serbia, ISBN 978-86-86663-49-8, pp. 509-519, http://www.cqm.rs/2010/4iqc/pdf/055.pdf
[9] Liu, L. Chen, Z., Zan, D., Lu, Y., Wang, H., (2010), RFID in Supply Chain Management, Int. Conf. on E-Business and E-Government, Guangzhou, China
[10] Miller, P., (2007), Hitachi's RFID powder freaks us the heck out, www.engadget.com/ 2007/02/14/hitachis-rfid-powder-freaks-us-the-heck-out, [last accessed 12.02.2011]
[11] WURFL, (2011), WURFL device database, wurfl.sourceforge.net/, [last acc. 12.02.2011]
[12] Yuan, Q., Xiaokang, Z., Qiong, Z., (2008), Key Technology and System Design in Mobile Supply Chain Management, Proc. of the 2008 International Symposium on Electronic Commerce and Security, ISECS'08, ISBN: 978-0-7695-3258-5

Acknowledgment: Research presented in this paper was supported by Ministry of Science and Technological Development of Republic of Serbia, Grant III-44010, Title: Intelligent Systems for Software Product Development and Business Support based on Models.