

THE MOBILE CONTROLLED RFID SYSTEM

Mikael Soini, Teppo Eeva, Lauri Sydanheimo, Markku Kivikoski

*Tampere University of Technology, Rauma Research Unit
Kalliokatu 2, FIN-26100 Rauma, FINLAND
E-mail: mikael.soini@tut.fi*

Abstract: This paper introduces the concept of mobility when controlling and monitoring RFID (Radio Frequency Identification) systems. Mobile controlled RFID systems enable the remote tracking of RFID tags. The RFID system automatically sends information about the tag movements to the mobile phone. The user can also find out which tags are within the operating range of known RFID readers. Mobile connection between the user and the RFID system is made through the GSM (Global System Mobile communications) network's packet-switched GPRS (General Packet Radio System) service. IP-based (Internet Protocol) communication format allows the system to be applied in different cases and enables the use of other wireless or wired connections. *Copyright © 2002 IFAC*

Keywords: Automation, Communication interface, Control, Mobile, Monitoring, Telecommunication, Tracking

1. INTRODUCTION

When developing supply chain management in order to improve efficiency and cost-effectiveness, automation is a dominant factor. An essential part of automation is identification. Radio Frequency Identification (RFID) is a potential solution for the near future and will in time at least partially replace manual solutions, e.g. bar codes. RFID tag features such as non-line of sight operation, reprogram ability, simultaneous reading of multiple tags, fast read speeds, increased data storage capacity and operating distances of several metres are the parameters that makes RFID superior to the bar code (Raza 1999). On the other hand the RFID tag price is still much higher than the price of the bar code which justifies continued use of bar codes in basic situations such as identification in consumer goods sales. RFID is not a direct replacement of the bar code because it can be used in other, more intelligent applications.

These include solutions associated with material flow, warehouse or supply management, wireless commerce, logistics, user identification, access control, burglar alarms, door and gate openings, toll payments and tracking equipment or materials (Stanford, 2003).

A traditional RFID system (figure 1) contains normally three parts: RFID tags, a RFID reader and a computer that controls the RFID reader. The implementation is usual local with a serial port connection between the reader and the host.

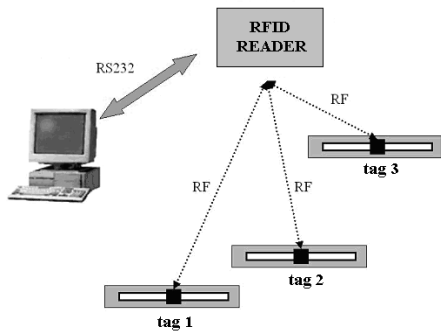


Fig. 1. In a typical RFID system the control and monitoring by a PC connected to the RFID reader by serial port (RS-232).

This paper presents the properties of the mobile controlled RFID system that differs from the above-mentioned traditional system in that it can be controlled and monitored remotely with a mobile station such as a mobile phone (figure 2). In this system the control commands and responses are transmitted through the GSM (Global System Mobile communications) network and using the GSM network's GPRS (General Packet Radio System) service. The packet-switched GPRS increases the data transfer capacity of the GSM network and so improves the system's usability. The developed universal set of control commands and responses between the RFID system and mobile control device flow through the Internet. The host server that is the mobile gateway server handles the user's commands and controls the RFID reader. The RFID reader communicates with multiple passive backscattering RFID tags.

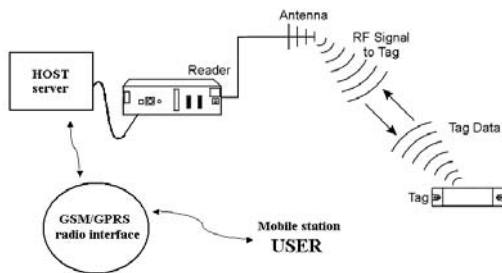


Fig. 2. The basic structure of the mobile controlled RFID system. The RFID reader communicates with passive backscattering tags. The host server or mobile gateway server controls the reader. This server receives commands remotely from the user.

This paper introduces the mobility in this system, system structure and its operation together with the newly developed communication interface. Applications based on these standard and global approaches allows the developed systems to be used in variety of ways. It is also the only way to achieve common acceptance of the RFID technology. In the final section the conclusions and future prospects are presented.

2. TELECOMMUNICATIONS AND MOBILITY IN THE CONTROL AND MONITORING APPLICATIONS

GSM (Global System Mobile communications) is the world's most widespread digital mobile phone standard. GSM is a European standard for cellular circuit-switched communications developed by the European Telecommunications Standards Institute (ETSI). GPRS is a technology which uses the existing GSM networks radio interface offering packet-switched networks such as the Internet. GPRS is the first step towards wireless all-IP (Internet Protocol) or 3G systems and is a developing environment with improving quality and reliability in wireless mobile applications. (Ruohonen, 2004)

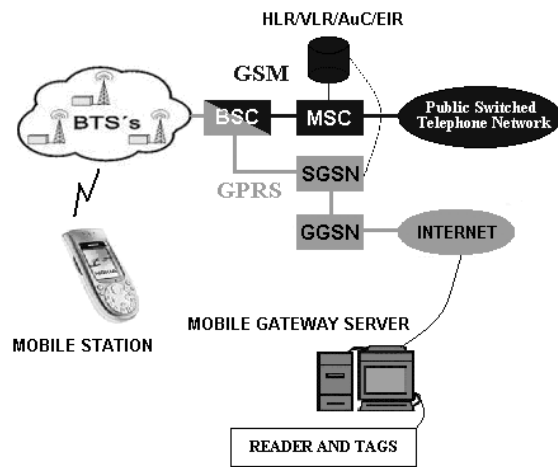


Fig. 3. Mobile control through the GSM network's GPRS service. The GPRS connection between the parties uses the basic building blocks of the GSM network; base transceiver stations (BTS), base station controllers (BSC) and different registers. Service GPRS support nodes (SGSN) and gateway GPRS support nodes (GGSN) bring IP-based Internet features to the GSM mobile phone system. (Samjani, 2002)

Packet-switched GPRS service improves the usability of mobile solutions. GPRS devices are always connected to the network, which saves the time consumed with dial-up-connection formalities in GSM applications. GPRS increases data transmission speed compared to GSM data which also enhances usability. Recently developed, more user-friendly mobile phones with big and colourful displays, fast-running applications and devices permanently connected to the network are the qualities which make the remotely controlled solutions important in logistics and manufacturing environments.

Figure 4 below shows the user interface (UI) developed for this system. The user can choose to follow-up particular tags, remove some tags from the follow-up or read the tag list from the mobile gateway server. Adding to or removing from the

follow-up list is achieved by entering the tag's serial number in the appropriate place. This system contains an additional feature that enables the user to control and monitor digital outputs and inputs. This feature gives more opportunities to the user for all-inclusive control and monitoring of automation systems. Different qualities of systems mentioned above are discussed in detail in section 3.

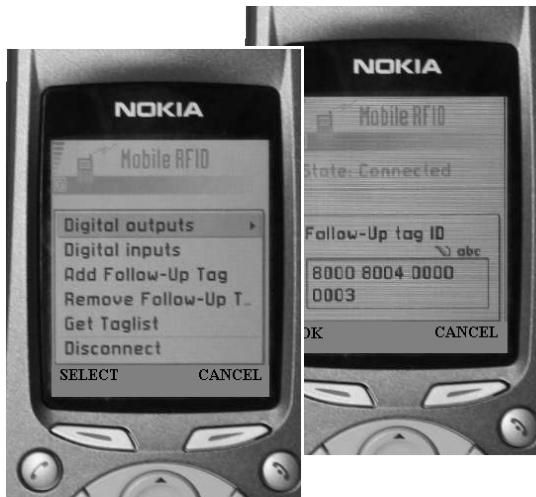


Fig. 4. Displays of the mobile station used in this mobile controlled RFID system. The photo on the left shows the main display of the UI and that on the right shows how the user can add a tag (serial number) to the follow-up list.

GPRS is a time division multiple access-based cellular system that enables the packets to be transferred in end-to-end packet mode communications. A user who wants to transmit data from a mobile station to server must compete with the other to gain access to the medium. The GPRS service then allocates channel resources consistent with the amount of data to be transferred (Chitre 2003). In this way the GPRS does not need a "fixed" connection or constant time slot from the GSM radio interface for the communication because data is sent in small addressed packets or bursts that can use different time slots. This is why invoicing is not based on connection time as in GSM but on the amount of transferred data (volume based charging). This leads to savings in phone costs.

A GPRS device receives a random IP-address from GPRS-backbone in every data connection phase. The GPRS device works as a normal IP-network device, which enables the unconstrained use of mobile solutions that are connected to the Internet or intranet. This quality enables control and monitoring different systems to be connected to a company's LAN (Local Area Network) from a distance through the IP network. GPRS is transparent from the user point of view so only the IP-network connected is apparent to the user.

GPRS is a step towards wholly packet-switched mobile systems that offer more transmission capacity than circuit-switched systems such as GSM. This leads to improved and more versatile mobile solutions, which can be used also in remote control and monitoring applications. The next steps in mobile technology are EDGE (Enhanced Data rates for GSM Evolution) and UMTS (Universal Mobile Telecommunications System). UMTS offers transmission speeds that enable mobile video transfer to be used in, for example, monitoring, identification and access control applications.

The use of mobile networks and in this case GPRS is one way to control and monitor this advanced RFID system remotely. Bluetooth and WLAN (Wireless Local Area Network) devices can also be exploited in this system. With these techniques the data does not flow through the mobile phone operator networks so the data transmission is free of charge. Naturally the transmission distances with Bluetooth and WLAN are only tens or hundreds of metres in length which limits the operating range to perhaps inside a building. In some cases it is practical to use a desktop or laptop connected to the Internet in the company's own local area network (LAN) or from another location. When using LAN or WLAN for data transmission the use of a graphic web-based user interface can be exploited for control and monitoring of the RFID system. The use of PDA (Personal Digital Assistance) devices are possible when using WLAN. In the case of Bluetooth and GPRS it is possible to use a mobile phone or a computer for control and monitoring. The use of these short-range wireless techniques or wired Internet (figure 5) can be put into effect easily because the communication in this system is independent of used transmission techniques. This communication format will be discussed in more detail in section 4.

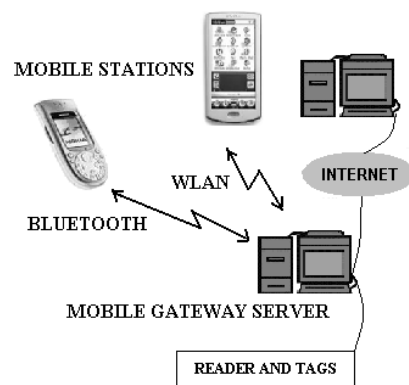


Fig. 5. Short-range wireless and wired remote control. Communication format and IP-based operation of the system enable the use of other wireless techniques like Bluetooth and WLAN or wired Internet in the control procedure.

3. THE MAJOR PARTS OF THE SYSTEM AND SYSTEM OPERATION

This mobile controlled RFID system consists of a mobile station, mobile gateway server, RFID reader and passive RFID tags. RFID tags used in this system operate on 915 MHz frequency band. These tags communicate with RFID readers according to the Auto-ID Center's UHF (Ultra High Frequency) specification. This open specification enables the development of features and performance required in track and trace, logistics, and supplying chain applications. RFID tag operating distances are a couple of metres and tags obtain operating energy from the reader's signal (passive backscattering technique) (Alien, 2003). The use of these UHF frequencies gives larger operating ranges and smaller antenna sizes compared to lower operating frequencies (135kHz or 13,56 MHz). Also electrical interference sources like the electro motors in industrial environments can be avoided in UHF frequencies (Nilsson 2002). On the other hand careful reader antenna placement and orientation with these high frequency radio waves is important because metals and liquids strongly disturb the communication between the tags and the reader.

The reader-tag network architecture supports point-to-multipoint communication. The reader integrates seamlessly into existing IT infrastructure using standard network protocols. An RFID reader is connected to the intranet and it can be controlled with a mobile gateway server through a TCP/IP (Transmission Control Protocol/Internet Protocol) network or serial port (RS-232) connection. In simple systems where the distance between the server and the reader is not too great it is possible to use a RS-232 connection. In situations where there are multiple readers connected to the server and/or the distances between these readers and the server are more than some tens of metres the use of a TCP/IP connection is inevitable.

The RFID reader keeps a list of every RFID tag detected in its reading range. This list is updated continuously when a tag arrives or leaves the reading range. All changes are sent immediately to the mobile gateway server. The user can operate the RFID reader through the mobile gateway server.

Consequently the mobile gateway server works as a connector between the user or mobile station and the RFID reader. The server transforms the commands from the mobile station and transfers them to the RFID reader. As mentioned above the RFID reader sends tag list changes to the server. In addition to this the server reads a tag list from the RFID reader every 30 seconds to ensure that the system is working properly. Using the tag list data, the server looks for any changes in state-of follow-up tags. If there are changes a message is sent automatically to the user.

When the mobile station user has a connection to the mobile gateway server the following operations are possible: Reading the reader's up to date tag list from the server, setting follow-ups to certain tags or removing follow-up tags, reading digital inputs, and controlling or reading digital outputs. This user operation with mobile gateway server is discussed further in section 4.

The sequence chart (figure 6) below shows an example of the operation of this system. Five parties are shown participating in the system operation. The user can define a set of tags to follow-up. Tags are entered on the follow-up list by writing the serial number of the tag to be followed (figure 4) and sending it to the server. After this the user receives information from the mobile station automatically when a tag or tags leave from or arrive in the area. If a tag is not in the user's follow-up list then the update is only visible at the server end. Information about this event can be obtained from the server by requesting a tag list.

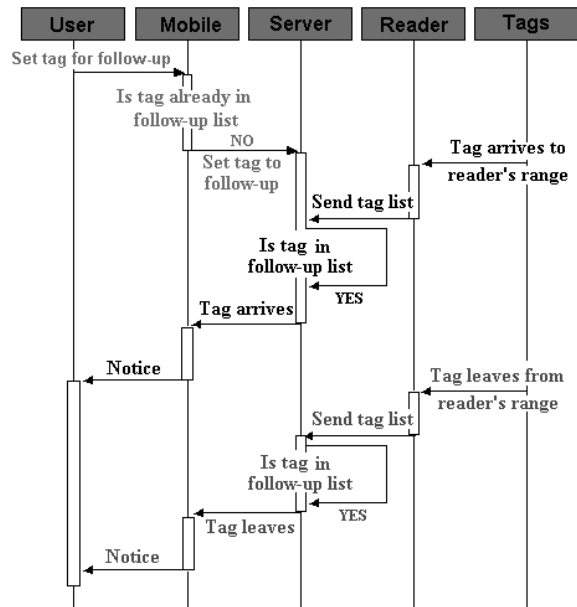


Fig. 6. Sequence chart when setting a RFID tag to a follow-up list. The server keeps a list of the follow-up tags set by the user. The server informs the user when a tag or tags arrive in or leave from the readers operating area.

The tag follow-up list is also maintained in the mobile station. This assists in removing the tags from the follow-up list. The user simply picks the serial number of the removed tag from the menu of the mobile station. This is sent to the server that updates its follow-up list. It is also possible to keep the whole tag list in the mobile phone to help enter tags on the follow-up list. Thus the user could choose a tag to be followed-up straight from the mobile phone's menu. This however does not work if a tag is not at the moment of set-up in the reader's operating range. In the following example the tag serial number must be notified in advance.

A person A sends a packet to a person B. B is spending time in the countryside. Packet delivery is critical so A sends an e-mail to B that a packet (tag serial number X) will be delivered to the local postal office some time tomorrow. B regularly reads his e-mails by GPRS-enabled phone and when he gets A's message he labels the packet (the tag) for follow-up. When the packet arrives at the post office's loading platform reader, B is notified automatically by a message to his mobile phone from the mobile gateway server that his packet is ready for collection.

4. THE GLOBAL COMMUNICATION INTERFACE

When planning the interface or communication format between the mobile station and the RFID system the main goal was to achieve compact, simple and comprehensive communication format. Compact format minimizes the amount of transferred GPRS data and thus it reduces costs of the use. This comprehensive communication is flexible that makes the addition of new commands possible in the future development.

The mobile gateway server works as an interface between the mobile station and RFID system. Communication between these parties is based on connection-oriented TCP/IP (Transmission Control Protocol/Internet Protocol). The set of universally used commands over this IP-network enables the use of IP-capable Bluetooth, WLAN and wired LAN in the system control.

The mobile gateway server transforms universal control commands from the mobile station suitable for the RFID reader and vice versa. It is possible to build the server to communicate with different manufacturers' readers. In this case the system forms a universal communication format from top to bottom, that is, from the tags to the user. This is a very important quality of this developed system because it makes the use of the system possible with different manufacturers devices and their various communication formats.

The following table 1 introduces the commands that can be used for control and monitoring of the RFID system. The use of connection-oriented TCP eliminates the need to transmit any acknowledgements to commands.

Table 1. Messages in tag management, tag follow-up, I/O port controlling and connection failure situations in the system operation

Tag management:	Explanations:
<i>GETLIST</i>	Get tag list from the mobile gateway server
<i>GETCOUNT</i>	Get list of active tags that are followed-up from the gateway server
Tag follow-ups:	Explanations:
<i>SETFUP</i>	Set a tag to follow-up list of the server. Serial number as a parameter.
<i>RMTFUP</i>	Remove a tag from follow-up list of the server. Serial number as a parameter.
<i>FOUNDFU</i>	Notification by the server of a follow-up tag's arrival in the reader's range. Serial number as a parameter.
<i>DEPFU</i>	Notification by the server of a follow-up tag's departure from the reader's range. Serial number as a parameter.
I/O ports:	Explanations:
<i>SETEXTOUT</i>	Set reader's digital output to on/off
<i>GETEXTOUT</i>	Read reader's digital outputs
<i>GETEXTINT</i>	Read reader's digital inputs
Errors:	Explanations:
<i>CERROR</i>	Communication failure. Parties cannot identify a command. Error code as a parameter

The following tables 2,3 and 4 introduce tag management and tag follow-up commands between the client (the user) and the server (mobile gateway server) in detail.

Table 2. Tag management command. The user requests a tag list from the mobile gateway server. The server replies with a list of tags in the RFID reader's operating range

Client: <i>SendCommand (GETLIST, 0)</i>
Server: <i>SendCommand (GETLIST, "8000 8004 0000 0004, 8000 8004 F103 0010, 8000 8004 0100 023F")</i>

Table 3 Tag follow-up commands. The client sets (SETFUP) or removes (RMTFUP) a tag (8000 8003 12FE 1ACE) to or from a server's follow-up list.

Client:

SendCommand (SETFUP, "8000 8003 12FE 1ACE")

Client:

SendCommand (RMTFUP, "8000 8003 12FE 1ACE")

Table 4 Tag follow-up commands. The server informs the user that the reader has found (FOUNDFU) a tag (8000 8003 12FE 1ACE), set for a follow-up or that the reader detected the tag departure.

Server:

SendCommand (FOUNDFU, "8000 8003 12FE 1ACE")

Server:

SendCommand (DEPFU, "8000 8003 12FE 1ACE")

5. CONCLUSION

This paper introduced the mobile controlled RFID system that can be used in many control and monitoring procedures. The user can operate the RFID system remotely with a mobile station through the GSM networks IP-based GPRS service. The connection is TCP/IP-based also from the mobile gateway server to the RFID reader. Communication on top of connection-oriented TCP/IP connection is made with a developed universal set of commands that can be used with different manufacturers' devices. Reader and passive backscattering tags communicate with the Auto-ID Center's open specifications. This standard approach, from top-to-bottom, allows the system to be used in various cases. Standard approach also makes the use of different IP-based transmission techniques (Bluetooth, WLAN and LAN) possible in some cases as an alternative to GPRS.

This tag tracking solution can be exploited in many cases such as manufacturing processes, warehouse management, logistics, and security. The next development will be to enable multiple users in the system. Further improvements may be made by increasing utilization of the growing number of RFID readers and tags in the system. The creation of chains of RFID readers makes more accurate and efficient positioning applications possible.

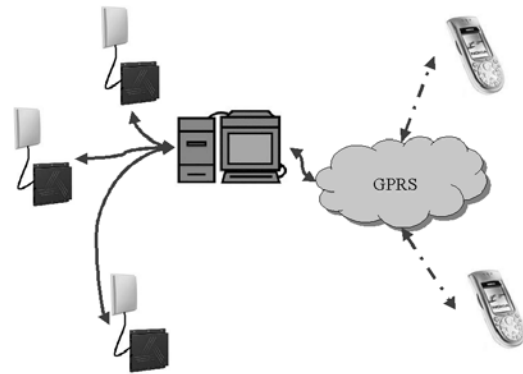


Fig. 7. Multiple users control and monitor multiple tag readers and tags in their operating range.

REFERENCES:

- Ruohonen, T., Raunonen, P., Soini, M., Sydanheimo, L. and Kivikoski M. (2004). Quality and reliability of GPRS connections. To Appear: 2004 IEEE Consumer Communications and Networking Conference (CCNC2004), Las Vegas, Nevada, USA, 2004.
- Samjani, A. (2002). General Packet Radio Service (GPRS). *IEEE Potentials*, **April/May 2002**, 4 pages.
- Alien technologies, RFID implementing (2003). http://www.alientechnology.com/mambo_alien/index.php.
- Stanford, V. (2003). Pervasive Computing Goes the Last Hundred Feet with RFID Systems. *IEEE Pervasive Computing*, **April-June 2003**, 9 pages.
- Nilsson, M., Hallberg, J. (2002). Positioning with Bluetooth, IrDA and RFID, pp. 16-21. *Master Thesis*, Lulea University of Technology, Department of Computer Science and Electrical Engineering.
- Raza, N., Bradshaw, V., Hague, M. (1999). Applications of RFID Technology. *RFID Technology* (Ref. No. 1999/123), IEE Colloquium on, 25 Oct. 1999. Pages: 1/1 -1/5
- Chitre, V.A., Daigle, J.N. (2003). Performance of IP-based services over GPRS. *IEEE Transactions on Computers*, June 2003, **Volume 52**, Issue 6, Pages 727 -741