# Mobile phone based SCADA for industrial automation

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#### **Abstract**

SCADA is the acronym for "Supervisory Control And Data Acquisition." SCADA systems are widely used in industry for supervisory control and data acquisition of industrial processes. Conventional SCADA systems use PC, notebook, thin client, and PDA as a client. In this paper, a Java-enabled mobile phone has been used as a client in a sample SCADA application in order to display and supervise the position of a sample prototype crane. The paper presents an actual implementation of the on-line controlling of the prototype crane via mobile phone. The wireless communication between the mobile phone and the SCADA server is performed by means of a base station via general packet radio service (GPRS) and wireless application protocol (WAP). Test results have indicated that the mobile phone based SCADA integration using the GPRS or WAP transfer scheme could enhance the performance of the crane in a day without causing an increase in the response times of SCADA functions. The operator can visualize and modify the plant parameters using his mobile phone, without reaching the site. In this way maintenance costs are reduced and productivity is increased. © 2006 ISA—The Instrumentation, Systems, and Automation Society.

Keywords: SCADA; Automation; Mobile phone; WAP; GPRS

#### 1. Introduction

The term supervisory control and data acquisition (SCADA) was first introduced in the 1960s at Bonneville Power Administration and was first published in the PICA (Power Industry Computer Applications) Conference Proceedings. The SCADA system is used for monitoring and controlling of industrial processes from remote areas. The need to monitor the process and possibly control the operation of industrial systems from virtually anywhere is becoming an important issue. However, with different types of platforms used in present SCADA systems, incompatibility has become the main obstacle [1]. Other problems in-

clude cost, security, accessibility, system integration, data integrity, and consistency [2].

Many companies are considering SCADA systems to provide access to real time data display, alarming, trending, and reporting from remote equipment by using different communication media such as Internet, private leased line (PLL), dial-up connection, satellite, and radio modem. Recent technological advances have made location transparency achievable through the Internet at a relatively low cost and acceptable level of security. Some of the potentially valuable developments are Intranet and Extranet. Nowadays, improvements in the visual interface of the SCADA GUI (Graphical User Interface) have fairly high-resolution graphical animations.

In spite of all these improvements, a need has emerged to access system information instead of controlling it from specific control centers.

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SCADA systems have been opened to the world via the Internet to meet this requirement. Despite all these improvements, the SCADA system needs a computer connected to the Internet. Recently there has been a growing trend towards personal computers and work stations becoming "portable" and "mobile." This has led to a big expansion of wireless networking, which is getting advanced in terms of technology and usage and penetration [3].

SCADA software usually exists in a computer, which carries out tasks of supervision and management of alarms, as well as data processing and process control. The communication is made by means of special buses or LAN networks. All these tools are executed normally in real time, and are designed to give the plant operator the possibility of supervising and controlling of these processes.

SCADA systems require both hardware and software for their successful execution. Userdesigned control parameters, graphical system diagrams, trend charts, alarm screens, and programmable control logic are some of the features of the software program for the SCADA systems. This paper discusses the use of mobile phone as a client for an industrial SCADA automation system. An experimental prototype crane system is monitored by a mobile phone in a sample SCADA application. An attempt is made to provide some insight into design considerations for wireless mobile phone based automation as used in modern SCADA automation systems. It is emphasized that with some basic knowledge of design considerations, it is easier to take the right automation approach and choose the right equipment for the task considered. Test results have indicated that the mobile-based SCADA integration using the general packet radio service (GPRS) or wireless application protocol (WAP) transfer scheme could enhance the performance of the crane in a day without causing an increase in the response times of SCADA functions. As distance to remote sites increases, it becomes more difficult to access them. In this case, SCADA becomes a better alternative to an operator or repairman visiting the site for adjustments and inspections. Distance and remoteness are two major factors for implementing the SCADA systems.

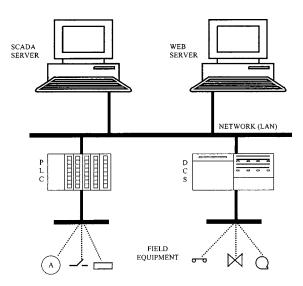


Fig. 1. Conventional SCADA system components.

# 2. Review of conventional SCADA system

SCADA is used to observe and supervise the shop floor equipments in various industrial automation applications. SCADA software, working on DOS and UNIX operating systems used in the 1980s, was an alarm-based program, which has a fairly simple visual interface.

SCADA systems using a variety of RTUs (remote terminal units) are used for industrial control and supervision all over the world. These systems drastically cut operating costs and allow the automatic supervision and reporting needed in today's regulatory environments. The main components of a conventional SCADA system [3–5] are RTUs at substations and plants, data processing units, and man-machine interfaces (MMIs). Conventional SCADA system components are given in Fig. 1 where all monitoring, processing, and control are constrained within the local area network located in the control center. Dedicated channels are required to guarantee the time responsiveness of the system.

In earlier days, an alarm sounding at control room meant that a crew would be dispatched to the trouble site to assess the problem. Based on their assessment, other crews would be called in, and those crews often would discover that yet an additional work crew was needed. Insufficient data with no control meant that all alarms were treated as urgent, since there was no knowledge about the importance of an alarm or the attention it required. Today, when an alarm goes off at a new SCADA

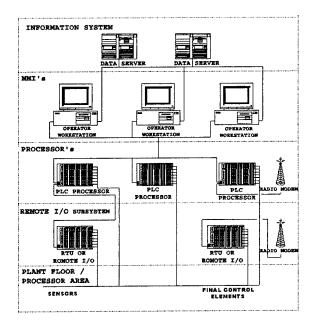


Fig. 2. Typical SCADA system architecture.

control center, an operator calls up a screen that shows the exact problem. The operator quickly determines the importance of the alarm and simply makes an adjustment or, if necessary, dispatches the appropriate crew directly to fix the problem. SCADA now provides monitoring of the entire automation process, including the treatment facilities. Presently, full control functions are being implemented in the SCADA automation system. SCADA systems allow equipment in many different locations to be monitored and controlled from a central location.

With the advances of electronic and software technologies, the supervisory control and data acquisition systems are widely used in industrial plant automation. It provides an efficient tool to monitor and control equipment in manufacturing processes on-line. The SCADA automation system always includes several functions, e.g., signal sensing, control, human machine interface, management, and networking.

#### 3. Web based network architecture

A typical SCADA system architecture is shown in Fig. 2. In this architecture, data systems are on the highest level, used for planning and storing data. The programs, including the server and client used by the operator and system, are on the MMI level. The PLC and RTU level is responsible for

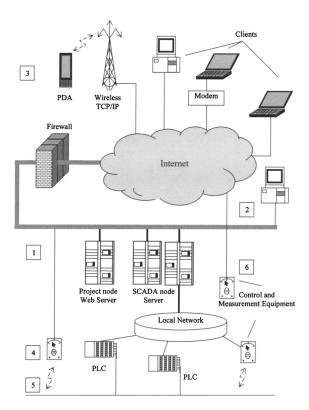


Fig. 3. The basic components of a Web access based SCADA system.

the connection between sensors and actuators in shop floor [6,7]. In this level, there is programmable logic controller software that controls shop floor equipment in a design manner.

The basic components of a web access based SCADA system are shown in Fig. 3 [8]. Web enabled SCADA hosts enable users to remote monitor and to control remote sites via a web browser. Hosted SCADA services allow users to monitor or control their remote equipment by using a normal web browser and logging onto a secure website.

Typically, a web access based SCADA system contains five elements. These are SCADA nodes, clients, project nodes, thin client, and network. The SCADA node communicates in real time with automation equipment. Typical automation equipment includes programmable logic controllers (PLCs), single loop controllers, direct digital control systems (DDC), distributed control systems (DCS), and input/output (I/O) modules. A full animation client uses an ActiveX control inside an Internet Explorer web browser to view real-time data, acknowledge alarms, and change set points, status, and other data. The client then communi-

cates directly with the SCADA node using proprietary communication links over a TCP/IP network connection. The project node is a centralized database server. It can be physically separated from the SCADA node or combined with it. A copy of the database of all SCADA nodes is kept on the project node. Remote configuration and graphics building occur on the project node using a Web server to exchange data with remote clients. The configuration of database and graphics are then downloaded to the SCADA node from the project node, which is a web server. The thin client interface supplies static snapshots of graphics as GIF files. No plug-in or ActiveX control is required. The thin client is intended for use with PDA, pocket PCs, and handheld computers but other ASP enabled web browsers can view the graphics. Real-time data, alarms, and changes to data are performed by means of a text-type interface. The thin client does not communicate with the SCADA node directly, it communicates directly to the project node only. Then network supplies the connection between the nodes and clients. Any TCP/IP network including local area networks (like Ethernet), a corporate Intranet, the Internet, or dial-up connections can be used. Internet and Web based SCADA systems have a lot of advantages, such as a wide area connectivity and pervasive, routable, parallel polling, redundancy, and hot standby, large addressing range, integration of IT to automation and monitoring networks, and standardization.

Many companies consider using the Internet for SCADA to provide access to real-time data display, alarming, trending, and reporting from remote equipment. However, there are three significant problems to overcome when implementing an Internet based SCADA system. The first is that most devices used to control remote equipment and processes, such as gas production wells and power distribution systems, do not have Internet communication capability already incorporated in their operating systems. The second is that the devices still have to be physically connected to the Internet, even when equipped through retrofit or in the factory with the necessary communications protocols. These problems must be solved at low cost and high reliability before Internet based SCADA can be implemented in industrial automation applications. The third is assurance of the data protection and access control. One solution to

these problems is to connect the device to a PC and have the PC make the connection to the Internet via an Internet service provider using secure socket layer. Unfortunately, this solution may not meet the low-cost criterion, and depending on configuration, can lack reliability. An alternative to using a PC is an embedded solution, a small, rugged, and low cost device that provides connectivity capabilities of a PC at lower cost and higher reliability.

The open nature of the Internet requires data security measures when implementing Internet based SCADA systems. Processes, procedures, and tools must address availability, integrity, confidentiality, and protection against unauthorized user. The open architecture of Internet based SCADA system combined with appropriate field equipment makes it possible to develop an integrated system such as mobile phone. However, interoperability requires data format and transmission protocol standardization. Use of Internet based SCADA automation system to monitor and control a plant has been proven to improve production and lower maintenance costs.

The introduced Java based application for a SCADA system was created with networking, compatibility, and support for an open geographical distributed environment as its main objectives. A consistent GUI for SCADA systems will enable inexperienced operators to become proficient in its usage with minimal training, thus reducing the cost requirement to invest in training staff on sophisticated and hard-to-configure systems.

A SCADA system gathers incoming automation system data for further processing by a number of distributed processes. However, existing SCADA information management systems cannot satisfy the new challenges as more and faster information has now become desirable by many users and players. Technological advances in networking have made it possible to develop a low cost communication system for accessing real-time power system information over digital network.

With a Java based application, any Java enabled browser can be used to view and control the SCADA system from any terminal of any existing operating platform within the control center. The application is platform independent, portable, where system data can be shared, reused, and accessed at a much-reduced cost. As the application is downloaded from the Web based server system

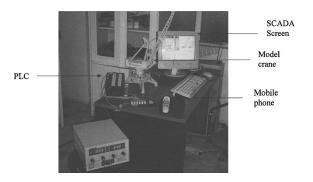


Fig. 4. Photograph of the mobile phone based SCADA application.

onto the client system for execution via a Web browser, scalability and performance are no longer tightly tied to the Web based server system. High performance requirements have also been addressed through multithreading in the application. This new Java based application, when applied to the SCADA system, provides an easy, effective and low investment means of accessing data. No special hardware is needed for the setup.

## 4. Developed application

In order to test the developed system, a model crane, which can move in two directions by using two dc motors, is designed. The model crane is controlled by using Siemens S7 300-312 IFM PLC ad SM334 I/O card. A CP5611 MPI bus card obtains the data interface between PLC and server. The SCADA program is WinCC, and the mobile phone is Siemens M50 containing 228-Kb user storage and is used for the proposed Java application.

The whole system consists of the model crane, the PLC with the control panel, mobile phone, and a PC. All the components of the mobile phone based SCADA application are shown in the photograph in Fig. 4. The model crane has three sensors, two of them are used for left-right direction and one of them is used for crane height.

The basic components of this model system are a model crane, computer, Siemens S7-300 CPU 312 IFM PLC, and SM 334 (AI4/AQ2) I/O card. The crane can turn itself around 360° and can act in the y axis. The movements of the crane can be controlled by using two dc motors. The PLC has been used as a bridge, which provides data transfer between the server and the test equipment. The most important part of the control action proce-

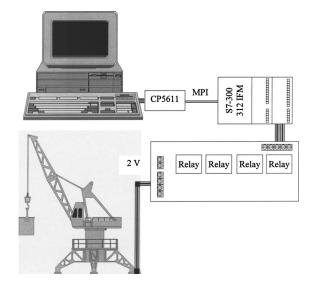
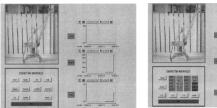


Fig. 5. Mobile based SCADA application block diagram.

dures is carried out by small programs in SCADA software. Data exchange between the server and PLC are realized by MPI bus protocol via a CP5611 MPI bus card installed on the server computer with a 187.5-KB/s data exchange rate. The mobile-based SCADA application model system block diagram is illustrated in Fig. 5. The server monitor and SCADA screen shot, and the remote control and remote supervision program screen shots are shown in Figs. 6 and 7, respectively.

Mobile phone SCADA GUI screen shot is shown in Fig. 8. The mobile phone (client) GUI has four specifications (graphical animations, value tables, alarm page, and remote control) as shown in Fig. 9. The parametric values of the prototype application are converted to graphical animations and listed in the value tables. Alarms that occured in the prototype application are given in the alarms section. Remote control of the application is carried out by using the remote control page.

The J2ME Application Program (JAP) operating



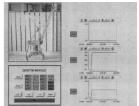


Fig. 6. The server monitor and SCADA screen shot of test prototype.

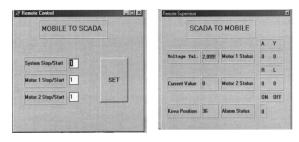


Fig. 7. Remote control and remote supervisor programs screen shots.

in mobile phone is prepared in Sun One Studio 4. The program has been tested in the Siemens M50 emulator and then downloaded to the mobile phone. The user can access the real-time information superimposed on on-line diagrams generated automatically using the mobile phone and routing techniques through the Internet. In addition, the user can control the operation of the automation system with the mobile phone through GSM (global system for mobile) base stations. The choice of the Java technologies offers unique and powerful features such as zero client installation, ondemand access, platform independence, and transaction management to the design of the on-line SCADA display at the mobile phone.

# 5. Design of the mobile phone based SCADA system

External data communication and integration from various information sources such as control centers, power plants, and substations have become a necessity. As more and more real-time information is being desired by many customers and vendors, existing information management sys-



Fig. 8. Mobile phone SCADA GUI screen shot.

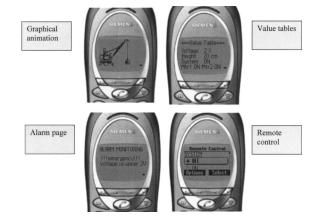


Fig. 9. Mobile phone (client) GUI specifications.

tems cannot satisfy the new challenges. Distributed SCADA has already become the trend of the future industrial automation system development.

In operation of the mobile phone based application, SCADA software in the server is operated first. Afterwards, the SCADA controlling program (SCP), which realizes the process of sending data to the server side program (SSP), is operated. Then, it transfers the data reading from the SCADA database to the Web page designated, where the ASP (active server page) is responsible for setting up the connection between the mobile phone and the SCADA system. The simple quantities of data received by the ASP, sending from SCP found in the Web server, is stored in the ASP.

This information reaches the ASP by means of GPRS or WAP after JAP in the mobile phone and this information is saved in the JAP database. Analyzing the data in this database, the JAP turns it into a value diagram, bar graph, text message, and various graph animations, which can easily be understood by the operator. As long as the program in the mobile phone operates, data between the mobile phone and SCADA system are automatically exchanged. The proposed mobile phone based SCADA automation system includes six levels as shown Fig. 10.

- 1. There are three servers in the first level: Web server, the master server, and the reserve server.
- 2. Firewall software or specially designed cards are used to ensure data security in the second level.
- 3. The operator station or control room, that contains PCs or thin clients, are installed at

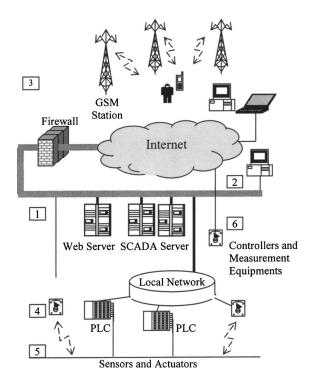


Fig. 10. The proposed mobile phone based SCADA automation system.

the central location in the plant. In the proposed system, a Java-enabled mobile phone is included as a client into the SCADA system.

- 4. Remote operator stations that can be connected to main server by its competence are used to inform the operator at the central control room. In today's SCADA applications, the number and the location of operator stations are not limited by means of Internet connectivity.
- PLC and other controllers, which are very near to the central control room, are placed in this level. The communication is realized by cables between PLC and other controllers to the central control room.
- RTU, Internet based equipments, and other controllers that are very far away from central control room are placed in this level. The communication media that are used in this level are private lease lines and radio modems.
- 7. Sensors and actuators are placed the lowest level of the SCADA automation system.

# 6. Designed software architecture

Internet/Intranet has been successfully employed in many areas for real-time applications such as audio stream and videoconference. An Internet-based SCADA system was also introduced [9] into a power system. Several prototypes and products have been introduced for on-line SCADA applications. However, most of the existing SCADA applications were set up based on the conventional computer technologies. An important challenge is how to integrate new services and network elements into the existing system. In this section is described an Internet based information accessing system based on an existing SCADA system.

The designed software architecture consists of three different programs: mobile phone program; server side program (SSP); SCADA controlling program (SCP).

#### 6.1. Mobile phone program

The mobile phone program is designed by using J2ME (Java Micro Edition) downloaded to a mobile phone with GPRS (general packet radio service) or WAP (wireless application protocol). The program sends the data required for the web server in accordance with the protocol using preferably GPRS or WAP internet access technology, receives the data sent by web server, and informs it to the user with the help of graphical interface analyzing this knowledge in its structure.

The application routine has two stages. At the first stage, current and voltage values of the system, state of motor 1 and motor 2 (ON/OFF), and bucket position value are sent to the mobile phone from the SCADA server. The data received by the mobile phone are interpreted by the J2ME application and some related graphical animations are offered to the user. At the second stage, an authorized user can control the SCADA system values via the mobile phone by using its user name and password. In our case study, authorized users can control the state of motor 1, motor 2, and the system on/off position by using the J2ME application program in the mobile phone.

#### 6.2. Server side program

A Server side program (SSP) can be designed by using any server side script (ASP, PHP, etc.) or

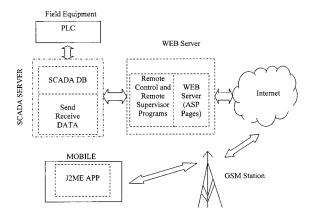


Fig. 11. Data flow diagram of the designed system software architecture.

Java Servlet (Server Applet). In this application, ASP is used as a SSP in order to get fast response to a lower number of users than Java Servlet that supports excessive users. It receives the request data sent by the program integrated into the mobile phone. It reads the values belonging to the state or position database located in the computer in which the web server is installed. These data are sent to the mobile phone via Internet in accordance with the program in the mobile phone and the protocol between them [10–12].

## 6.3. SCADA controlling programs

This program is installed in the same computer with the SCADA system and has a visual interface, receives the data pertaining to the state of the system connecting with SCADA, and saves it to the condition-stating database in the computer in which the web server is installed. Two different programs have been designed and used to monitor and control the SCADA system via mobile phone. The remote control program (mobile to SCADA) has been used to control the SCADA system via mobile phone, while the remote supervisor program (SCADA to mobile) has been used to monitor the SCADA system via mobile phone. A data flow diagram of the designed model system software architecture is illustrated in Fig. 11.

TCP/IP offers reliability by providing connection-oriented, end-to-end reliable packet delivery through an Internet network. It does this by sequencing bytes with a forwarding acknowledgment number that indicates to the destination the next byte the source expects to receive. Bytes not acknowledged within a specified period are re-

transmitted. The reliability mechanism of TCP/IP allows devices to deal with lost, delayed, duplicate, or misread packets. A time-out mechanism allows devices to detect lost packets and request retransmission [13].

#### 7. Conclusion

In this study, a Java enabled mobile phone has been integrated into the SCADA system as a client. Therefore the obligation of the SCADA system to work with a PC is not necessary. Since the monitoring and control of the plant process is performed with the use of present GSM base stations, no cost of network setting is required. The exchange of data with the SCADA system is accomplished through GPRS or WAP, so the expenditure of connection is considerably low.

The conditions in a process plant of an automation system are harsh and the site is remote. Resources for data communication are difficult to obtain under these conditions: thus a wireless channel communication through a mobile phone is practical and efficient in a process control environment. The mobile communication industries and the public have a strong interest in the WAP technology application in mobile phone networks. The WAP API (application program interface) in power industry applications is one of the areas that require extensive investigation. The objectives of this study are replacing the existing conventional SCADA system with one new mobile based system to control the sample crane, increasing the SCADA attain envelope to include all of the locations not currently reached, providing a SCADA system with WAP based software applications, and performing these purposes by installing minimum new hardware.

SCADA systems are alarm based systems and these alarms are monitored and controlled by an operator in a control center to inform maintenance operators when needed. This type of conventional alarm management system can be affected by human based faults. Integrating the mobile phones of the maintenance operators to the SCADA systems can minimize these faults. The maintenance and authorized operators can monitor and also control the system with their java enabled mobile phones by using their user name and password. The alarms occurring in the system can be sent to the authorized personnel or operators as a SMS message so that system security can be maximized.

Response time of the mobile phone based system is set to 10 sec, that can be changed by the user as required. In addition, the user can also get information about the SCADA system whenever they want.

By using a mobile WAP phone, shop floor personnel have access to critical information wherever they may be, and can take corrective action in a timely manner. Instead of being chained to a computer terminal, plant engineers and automation professionals now enjoy a new tool that offers greater mobility, thus making workers more productive, while maintaining the ability to monitor the integration of real-time data, alarm, and historical information in everyday plant operations. As distance to remote sites increases, it becomes more difficult to access these sites. Therefore SCADA becomes a better alternative to an operator or repairman visiting the site for adjustments and inspections. Distance and remoteness are two major factors for implementing SCADA systems.

The mobile phone based SCADA automation provides a cost effective solution to control and automate of the flow of information for small to medium size process plants. The proposed mobile phone based SCADA system has the capability of reporting selected process values and equipment alarms, giving GUI about process, remote controlling, and refreshing process data in a user-determined timely manner.

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