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An Internet Based Distributed Control Systems: A Case Study of Oil Refineries

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Abstract

An Internet based Distributed Control System (DCS) is presented in this paper for monitoring real time data using ordinary web browser. Each DCS will be connected to the central server which will be the system web server. The proposed system is based on the three-tier client-server model. The application server is written in C#.Net. SQL database server 2005 is used for all the DCSs local database servers and for the system database server. Monitoring real time system alarm and all historical records are considered as part of the proposed system. The North Oil Refineries of Baiji (NORB) in northern Iraq is considered as a case study for the developed system. These refineries have twelve independent DCSs which are connected in a mesh network to form one system similar to an ordinary Supervisory Control and Data Acquisition (SCADA) system.

Keywords: DCS, SCADA, Three-Tier, Client Server, OPNET, HMI

1. Introduction

Computer networks have already seeped to every domain of social economy and industrial operations. Local Area Network (LAN), Intranet and Internet technologies improved the industrial operations in general and specially in the case where information sharing becomes a necessity for an enterprise. Monitoring industrial real time data and executing some control operations using web browser is one of new tools in the market [1]. Using the Internet as communication backbone or as application services provider will save time, effort and cost. Once the infrastructure is made available, the possibilities are enormous [2].

An efficient, fast and effective control system has become a vital need in industrial sector. An Intranet/Internet and SCADA system interconnection based on industry-accepted communication standards is offered as a solution. The interconnection permits links between SCADA system and company users within Intranet/ Internet. The use of open standards makes the connection of SCADA systems and generally all control systems such as Programmable Logic Controller (PLC), DCS possible with the new IT advances. Internet based SCADA system offers such solution by enabling any user (client) to supervise and control all operations remotely from any part of the world with Internet connection by any web browser.

The architecture of SCADA system changed from centralized computing systems to networked distributed computing [3]. Third generation SCADA systems (networked SCADA) are now built with a distributed architecture in which the power of a master station is distributed over a number of processors connected together by LAN [4,5]. Connecting several independent DCSs in one Intranet can be considered as the same approach to that of the third generation SCADA systems.

Many researchers have applied Internet/Intranet technologies to improve certain functions of control systems. The major parts of these researches are focused onto Internet based SCADA system for power plants industry. The application of Internet technologies in [6-8] allows free and flexible acquisition of real time data from power systems. A remote supervision control system in power plants based on web services was presented in [9]. In [10, 11] an internet based SCADA systems for power plants taking as case study the power system in Montenegro and Cameroon were presented. Other works focused onto the use of Internet for supervising and controlling some simpler systems such as education laboratories [12], or

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multi-units industrial facility [2].

An Internet based DCS usually deals with very complex systems of large number of control points in the field. In [13], three layers SCADA system was simulated where OPC service protocol is used to solve the compatibility problem. An Internet based systems to allow monitoring of a DCS was presented in [14,15], while a method for managing DCS via company Intranet/Internet was considered in [16], and the design of remote real time supervisory system based on OPC was proposed in [1].

The NORB is a large industrial complex located on various sites scattered around the city of Baiji about 200km north of Baghdad. This complex comprises four large refineries: 1) Salah Aldine-1; 2) Salah Aldine-2; 3) North; and 4) Chemical Products. Also, six other refineries outside the region of Baiji form part of the same complex direction. Each refinery has many DCSs controlling several chemical processes. These processes are independent on each other and are installed at different geographical locations. Each DCS acts as standalone control system with its private communication network and Local Control Room (LCR). DCSs in operation are based on new information technology (IT) with open standards communication protocols such as TCP/IP protocols using fiber optic Ethernet for data transmission between field and LCR.

Connecting independent DCSs in the NORB in one system based on Intranet and connecting the system server located in the Central Control Room (CCR) to the Internet will be the principal part of the present research.

2. OPC-DCS Architecture

The DCSs have long been employed in industrial fields to process real time data in chemical and other critical processes. DCSs are widely deployed in automatic control and play increasingly vital roles in petroleum refineries. The dominating DCS products in Iraq refineries include Yamatake, Bradley, and Honeywell. All these systems are based on open standard with possibility to use TCP/IP communication protocols. A DCS is a complete system that includes closely integrated operator stations, control modules, and remote I/O (for interfacing analog and digital real world signals). The DCS is characterized by distributed intelligence in which each front-end controller is a microprocessor-based system. A central computer monitors and coordinates the entire network of intelligent controllers and devices. The intercommunication within the system is via digital communication, and thus a DCS possesses all the benefits associated with digital transmission which include less copper costs, stronger immunity to noise, longer transmission distance, higher reliability, and better re-configurability.

Figure 1 shows a typical industrial architecture of a Yamatake DCS used in NORB. It is based on the use of DOPC which stands for Dependable OLE for Process Control, where OLE stands for Object Linking and Embedding developed in 1996 by the industrial automation industry. DOPC (DEO OPC) is a trademark of Yamatake OPC specifies the communication of real time plant data between control devices from different manufacturers. The OPC Specification was based on the OLE, Component Object Model (COM), and Distributed COM (DCOM) technologies developed by Microsoft for the Microsoft Windows operating system family. The DCSs from other vendors obey the same main blocks. DCS is based onto 10/100 Mbps optical fiber Ethernet used to interconnect all DCS parts. The data collected from fields is transferred to be projected into Dependable Open Supervisory Station (DOSS) as Local Control Room (LCR). A copy of real time data is stored into the DEO Open History Server (DOHS). DOHS can be considered as local Web server for external client [17].

3. Client Server Multi-tier

Complex control system such as SCADA, DCS, and PLC systems have evolved from mainframe based system to client-server architecture model. The client server architecture is more reliable system and very attractive model because it can be subject to network topological change. Client server architecture can be built using the two tier model where the first tier is the client and the

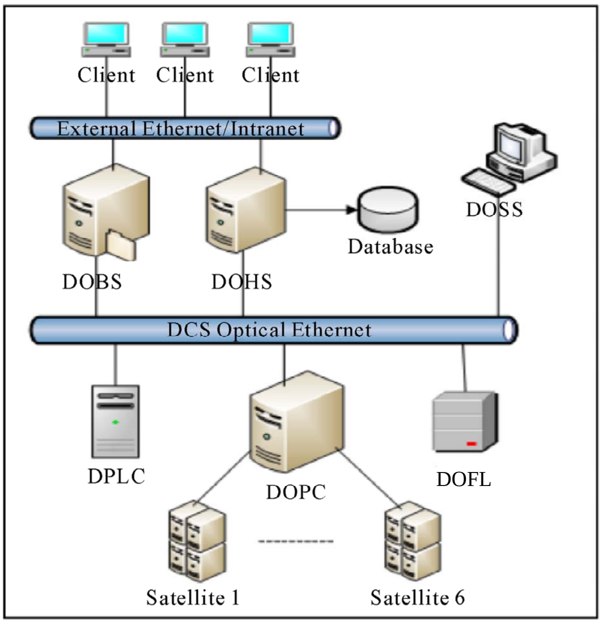

Figure 1. OPC DCS architecture.

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second tier is the server. The two tier client server model generally uses a database management system (DBMS) that provides the server and manages the client network connection both the client and the Server co-operate in executing the application, but the client contains all of the application logic as depicted in **Figure 2**. The server contains the DBMS which hides the complex functions that are needed to manage the data [18].

The three tier model introduces an additional element, or the middleware between the client and the server. The middleware runs on all machines that host a client or server. The task of the middleware is to provide services to clients or servers to enable efficient delivery of operation requests and return of results. The middleware may typically provide other features, such as distributed system management facilities as shown in **Figure 3**.

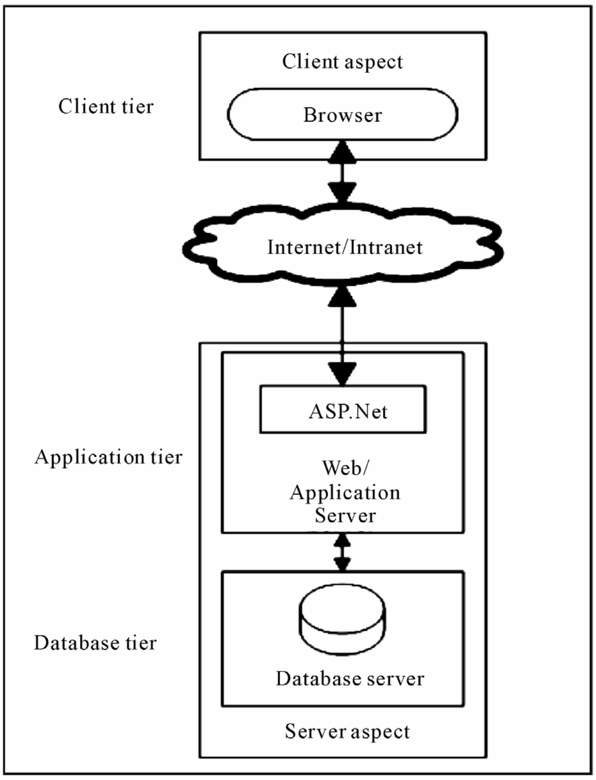

Figure 3. Three-tier client server system.

The flexibility and containment is provided in the middle layer of the three-tier architecture, allowing changes to be made relatively quickly and easily whilst they are at the same time localized in the middleware. This can be achieved with the minimum changes to the graphical user interface, or the database [19].

Internet based control system usually uses the three tier client server model as it is more practical for real time monitoring and control applications due to its flexibility and scalability [20].

4. Development of an Internet Based DCS

4.1. Problem Definition and Modeling

DCS is usually used to control complex industrial installations with a large number of controlled points in the field. DCS has a distributed architecture with nodes (satellites) acting as bridge between industrial fields and DOSS. As an example, one DCS of type Yamatake can support up to 60,000 tags (controlled points) distributed over 32 nodes as shown in **Table 1**. In the existing NORB only six distributed nodes are being used to collect information and control 2400 points in the field [17]. Yamatake DCS uses Windows NT, and Windows 2000 or newer versions as operating system, SQL server 2000, 2005, or 2008 as DBMS, associated software packages for software platform and optical Ethernet solution for control/information network.

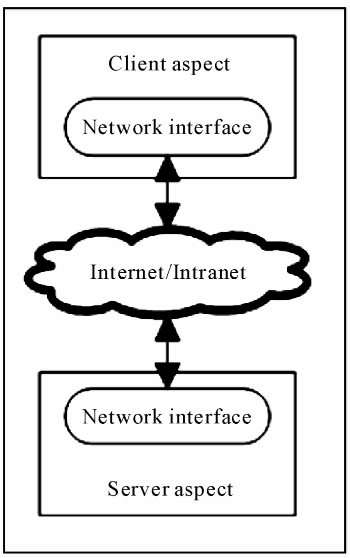

Figure 2. Two-tier client server system.

DOHS Is the local historical server to collect plant data through the DOPC and store it in its file [17]. The developed system considers each DCS as Remote Terminal Unite (RTU) for a global SCADA system. Local server for each DCS (local DOHS), will be connected to the system server via Intranet/Internet. Real time data collected from the field of each DCS are stored in local DOHS and a copy is sent immediately to the system database server in the CCR. The depicted adopted model is shown in **Figure 4**.

Due to the large collection of devices used in an oil refinery, it is vital to use simple Human Machine Interface (HMI) to represent data by Internet browser. In this work C#.Net is used to build the middleware layer (server side) applets. The system server enables the function of globalization of information of all DCSs through unique web

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Table 1. Yamatake system capacity.

Tags supported		60,000 parameters/DOSS
Total nodes	System-wide	126 nodes/network
	DOSS	32 nodes/NT cluster
	DOPC/DOPL	96 nodes/NT cluster

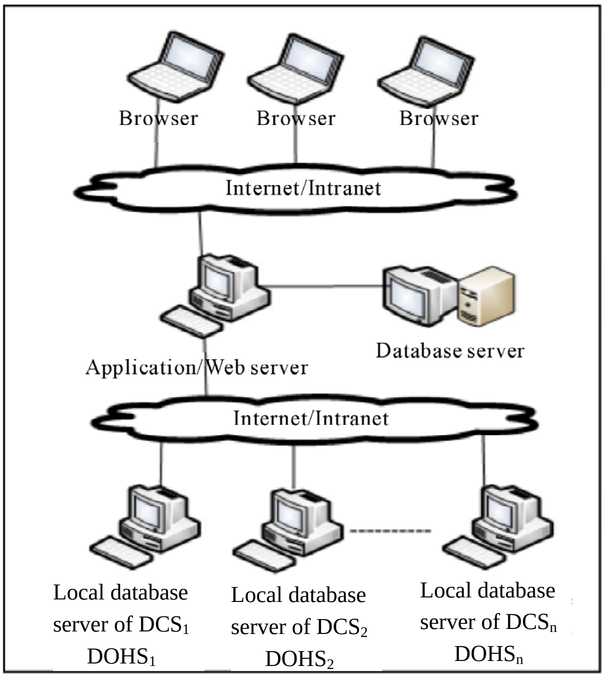

Figure 4. The adopted model of the network.

server. The database system server is connected to the system web server and then to the internet.

4.2. Architecture Design

4.2.1. Database Architecture

The adopted system architecture is based on connecting all DOHS for all DCSs to the system database server. Data from different DCSs are grouped in the system database server as one SQL table for one DCS. Every DCS will have a data table with columns (field) representing collecting data (data from specific device) and new line is added for each updating period. New tables are generated at midnight each day, while the old tables are classified as historical database. From the official site of Microsoft, it is recommended to use SQL server 2008 specialized edition for web application as DBMS because tables with this type of DBMS are with unlimited field and lines.

4.2.2. Real Time Data Transmission Network

System design must satisfy the requirement of real time data for critical process control system. Each node (satellite) can have maximum throughput of 19200 bps as specified for serial communication standard RS-232 used in the DOPC [17]. Keeping in mind the future extension each DCS will be considered as having 10-satellites, the DCS Bit Rate (BR) is then given by:

$$BR = 19200 \times 10 = 192000 \text{ bps} = 24000 \text{ Byte/sec}$$

which is the maximum possible bit rate that can be uploaded from one DCS in LCR to the system server in CCR.

In order to validate the real time network design, the network in **Figure 5** is simulated using OPNET modeler 14.5. FTP is the principal simulated protocol because it is responsible of uploading data from LCR to CCR. Other protocols are simulated which offer other services as database access, VoIP with PCM quality, and E-mail. The configuration of the simulation input is based on the maximum possible BR of each DCS and that each refinery as having three DCSs. Links between nodes are of the same type with bandwidth of 44.736 Mbps point to point link from the archive of OPNET. The displayed graph shown in **Figure 6** confirms that the communication network is a real time network with maximum delay time not exceeding (0.4 sec).

4.3. Software Solution

The developed Internet based control system uses C#.Net as programming platform. The main program resides in the web server side, so at the client side no programming requirement is needed. The program is built using many modules, and **Figure 7** gives a simple flow chart of the

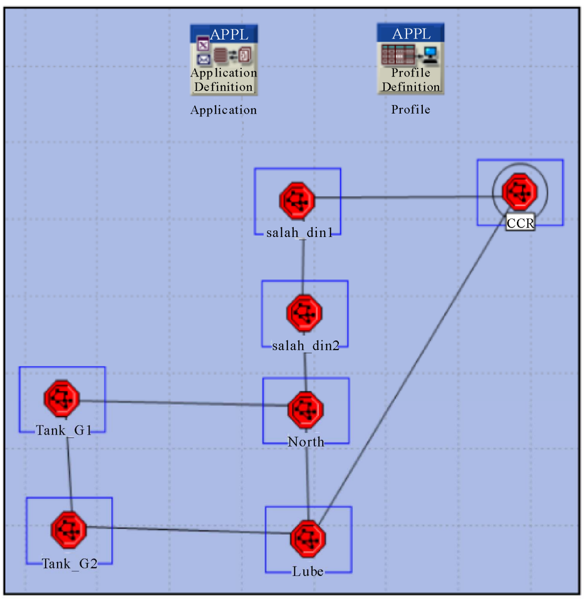

Figure 5. Simulated network.

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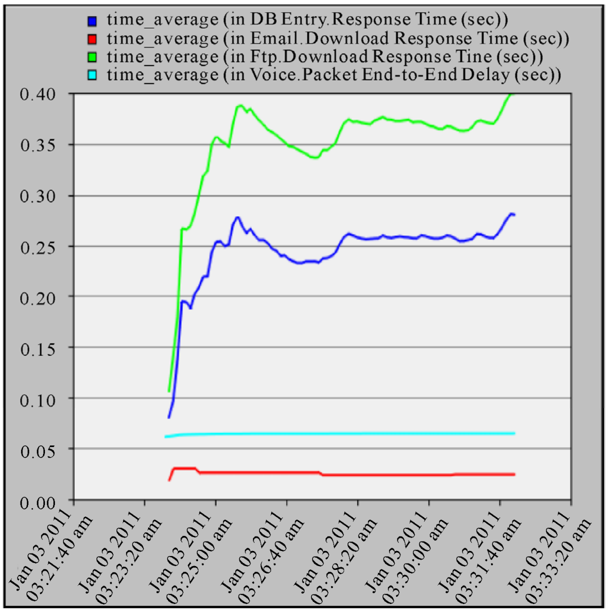

Figure 6. Time delay simulation result.

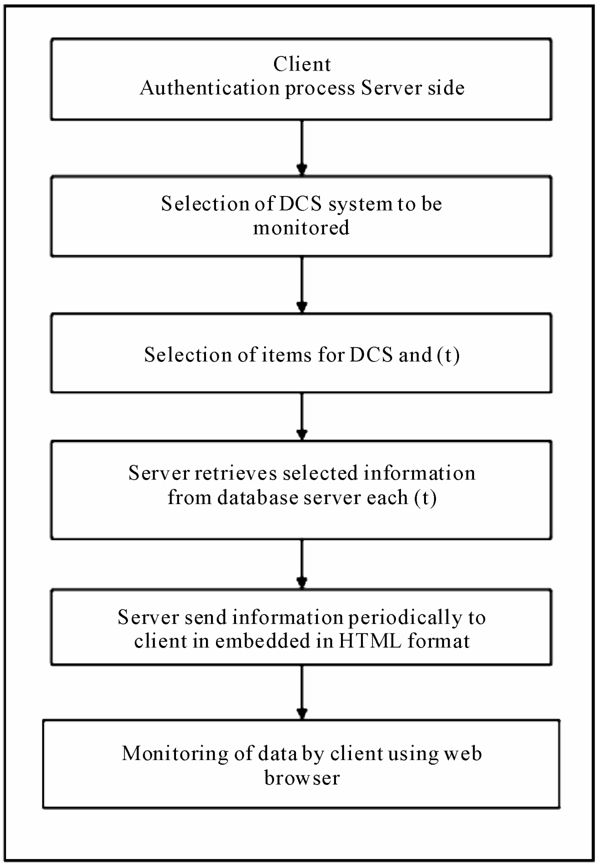

Figure 7. Data monitoring by client.

supervisory process. The client uses ordinary browser to connect to the desired site, and sends HTTP request which creates a new TCP connection to server and receives information on HTML format.

The first stage is the authentication process for the client by a user name and password, eventually encryption based on public key can be used [21]. After authentication a first form with all DCSs are listed as shown in **Figure 8**. HMI uses button, selection boxes and other controls available in the visual studio 2010 toolbox library. The second form represents all field sensors data for a selected DCS to be monitored as shown in **Figure 9**. After selection of data to be monitored, the server will send a request to the database server to retrieve needed data. Web server then sends the data embedded into HTML format to the client to be supervised. Data can be represented in numerical form, particularly when more than one sensor is to be monitored at the same time, or in graphic form as depicted in **Figure 10**. The process continues at each period by retrieving latest data from database table and sending it to the client until stopping request is made by the client. The period of updating time is fixed by the client with minimum value of one second.

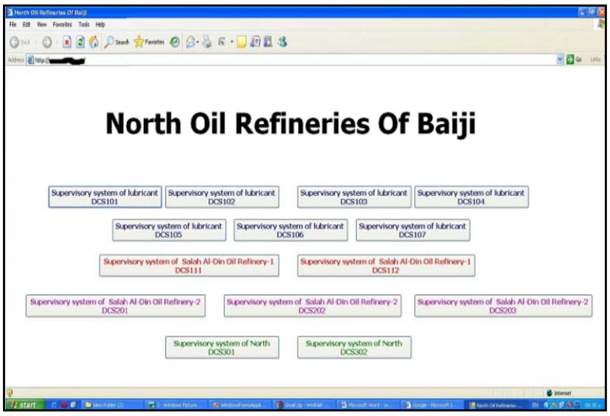

Figure 8. All DCSs listed.

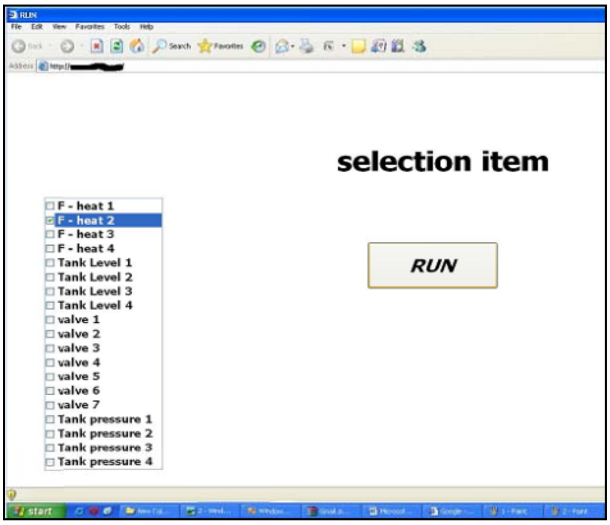

Figure 9. Field sensors of selected DCS.

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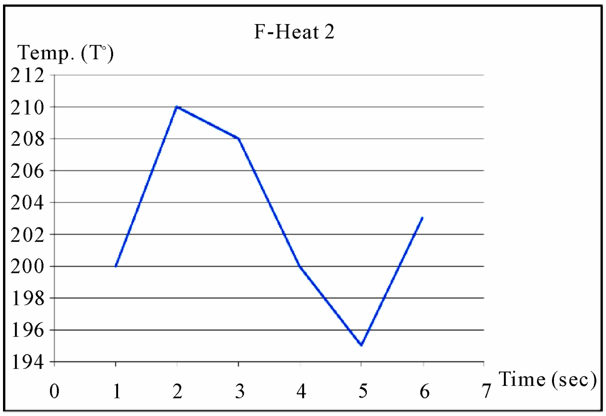

Figure 10. Heat of device number two.

The client applet is embedded in an HTML document. The user will attempt to connect to the server through the applet. The client applet will act as a listener only, listening for data on the socket that arrives from the server and updating the graphical display (HMI) to reflect changes in the status of the sensors at the host.

An alarm will be raised if any of the switches indicates an abnormal operational condition, or when the load/ temperature limit is exceeded, so that appropriate corrective actions can be taken.

5. Conclusions

The architecture and design of a distributed real-time control system based on the interconnection on several DCSs has been presented. The connection of unified system to the Internet via system server and based on three-tier client server was considered. The feasibility to monitor and control large number of field parameters from the Internet was demonstrated. Using OPNET, the real time data network connecting different DCSs was simulated based on geographical locations of the refinery blocks. The program prototype was tested for data samples with the designed simple HMI and a satisfactory result was obtained. It follows that this approach may be considered to interconnect a large number of industrial DCSs using open standards.

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