

SOFTWARE PLATFORM FOR ONLINE PROCESSING OF DATA FROM SENSORS USED TO MONITOR ENVIRONMENTAL PARAMETERS

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Abstract: *This research discusses a system for centralizing data in real-time, using the Internet, from sensors deployed in remote locations used to monitor environmental parameters like temperature, humidity, light intensity and other physical conditions. Using Oracle XE or 11gR2 database, Oracle APEX, and other third party open source software for developing the software platform, the solution it is different from others because it is scalable and not constrained to a specific type of application, giving the end user the advantage for manipulating the monitored data the way it is needed.*

Key words: *real-time, remote, monitoring, application, server, database, open source.*

1. INTRODUCTION

In production, certain processes must occur under proper physical environmental conditions. In order to achieve a controlled environment, specific environmental parameters (temperature, humidity, pressure) must be measured or monitored. This is done by deploying sensors (thermometers, hygrometers, manometers) in the location where the production process takes place.

A sensor is a device used to detect and measure physical phenomena and convert it into an electronic signal [13]. In order to achieve a higher production rate, the sensors should be able to send data automatically to a central computer. The result of the monitoring process consists in displaying the measured values acquired from the sensors in reports with tables and graphs.

Sensor manufacturers sell their products with a software package for viewing and filtering the monitored data. The monitored data is usually stored inside the sensor internal memory and sent to a database (MySQL, Microsoft Access, Microsoft SQL, FoxPro), or text files (*.txt) at time intervals. If several sensors from different manufacturers are deployed in the location where the production process takes place, then in order to view the measured values, the end user will access the data using the specific software, for the specific sensor from the specific manufacturer. Beside, even if all the manufacturers' sensor software export data in text files, the data from the files will have a customized format, according to the manufacturer, meaning that it will take a lot of time to centralize data from these files into one file with a global format even if all the sensors measure the same type of physical phenomena.

This paper describes a solution for automated centralization of environmental parameters measured data from different sensors deployed in locations with special environment requirements, into one software platform and centralizing the results in one user interface.

Other examples of monitoring scenarios: metrology labs, weather monitoring (gathering weather data like wind speed from several weather stations in the field), greenhouse control (temperature, humidity and light intensity), precision agriculture (provides data to farmers in the field about irrigation, pest control, localization of animals in the field), machine manufacturing process automation (surveillance of the production process from remote locations), process control (monitor moisture content of wood during the drying process in real-time), vehicle guidance (remote monitoring of an autonomous system) [3, 7 and 10].

2. CONCEPT AND SOLUTION DESIGN

The computer was designed to do the work for us. By using a programming language (C++, Java, PL/SQL) we tell the computer what we want it to do.

2.1. Monitored location

An example of production process that requires a controlled environment is a greenhouse for mushrooms culture (Figs. 1 and 2).

To ensure optimal conditions for mushroom cultivation it is necessary to monitor the temperature, humidity, light intensity and air flow. These parameters are measured using sensors (thermometers, hygrometers, lightmeters, air flow meters) positioned inside the greenhouse according to the cultivation technology.

The greenhouse atmosphere is maintained by an air conditioning installation that adjusts the air flow according with the data provided by the sensors.

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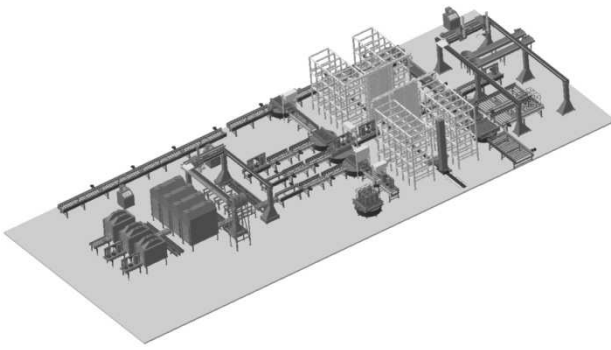


Fig. 1. Virtual prototype of mushroom cultivation production process.

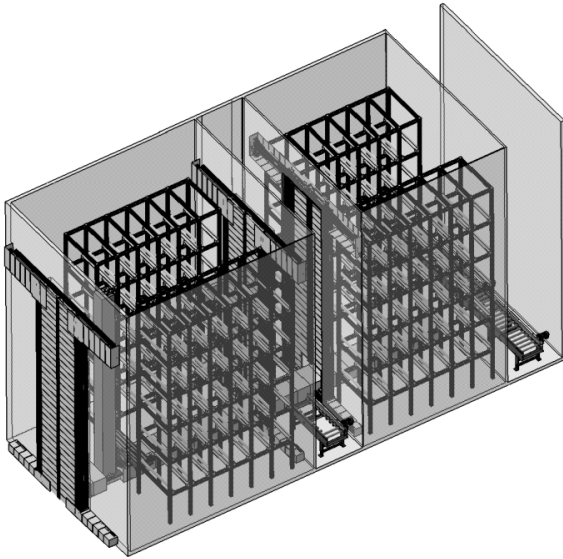


Fig. 2. Virtual prototype of mushroom cultivation greenhouse.

2.2. Monitoring and processing of data

A sensor, in general is a battery-powered device deployed in a location that require monitoring of certain environmental parameters (like water level, pressure, movement). The main architecture of a sensor consists of a sensing unit, a processing unit, a transceiver unit and a power unit. The basic tasks performed by a sensor are: sensing activity (measuring physical phenomena), communication (sending data to base) and data processing (mathematical algorithms applied over measured data) [13 and 14].

The concept of the software platform for online processing of data from sensors used to monitor environmental parameters is described in Fig. 3 [5, 6, 8, 9, and 11]:

- Sensor – any type of sensor that can be connected to a computer by special interface adapter, wireless, Bluetooth or other connection type.
- Data Storing Computer – a desktop computer where the values of the measured parameters received from sensors deployed in the field are stored locally. The computer must have access to internet. It is not an industrial computer.
- Application Server – the computer that processes the monitored data. It receives data in real-time from the storing PC. Also it hosts the web user interface which allows users to view the data.

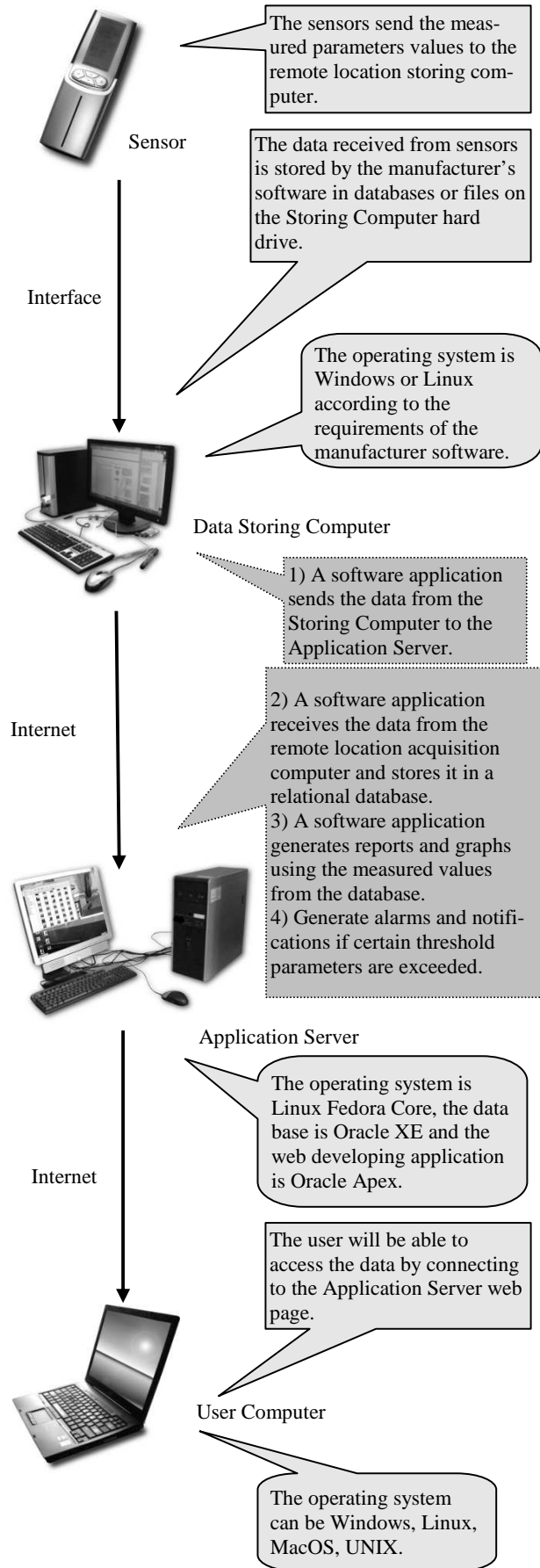


Fig. 3. Concept solution. The dashed callouts indicate the original contribution of this research.

User Computer – any computer that has access to the internet and an internet browser. Can be desktop PC, notebook, tablet PC.

The sensors send the values of the monitored environmental parameters to a computer for storing. The data storing computer is also located in the same location as the sensors.

The operating system of the storing PC from the remote location can be Windows or Linux according to the software of the manufacturer. Some sensor manufacturers provide software for both Windows and Linux platforms.

This research implies the developing of a software application that sends the monitored data from the storing PC to a server through internet.

Another point of this research is the developing of software application that inserts the received data from the remote location into a relational database.

The database is Oracle XE or in case of industrial use a licensed Oracle 11gR2 is recommended.

The last step of this research consists in the developing of an application for reporting results over the internet. The software application will be designed with Oracle APEX and will generate web pages with tables and graphs with values from the database.

Oracle APEX (Application Express) is freeware and can easily integrate code like PL/SQL, JavaScript, XML, CSS.

PL/SQL [15] (Procedural Language/Structured Query Language) is Oracle Corporation's procedural extension language for SQL and it is used to manipulate data (select, insert, update, delete) from tables and write procedures and functions in Oracle relational database.

JavaScript is a programming language used to dynamically manipulate items in a web page in real-time.

XML (eXtensible Mark-up Language) is used for data transfer.

CSS (Cascading Style Sheets) defines how to display the web page elements.

By developing a web user interface, the data can be accessed using an internet browser (Internet Explorer, Mozilla Firefox, Google Chrome, Apple Safari...) from any operating system Linux, Mac, Windows and from any location with internet access (work office, home, public places like a coffee shop using wireless).

Also the application must generate alarms, notifications, email and phone messages (SMS Short Message Service) if certain threshold environmental parameters are exceeded.

The original contributions of this research are highlighted in Fig. 2 by dashed callouts and consist in the developing of the management platform for the monitored data manipulation using freeware and open source software. By taking advantage of the data that is automatically inserted in the database, also other side application that make use of environmental parameters values can be developed.

A relational database is a database in which the data is stored in tables (predefined as categories) that are linked by relations. The relational database was invented by Edgar. F. Codd at IBM in 1970. The programming language for interacting with a relational database is SQL

(structured query language). An advantage of a relational database is that it is extensible (new tables can be added and linked with the existing tables).

A simple example of holding data about products in a relational database:

- The first approach is using one table (Fig. 4). The table named “PROD_1ST” has three columns: “P_ID”, “P_NAME” and “P_SN”. The column “P_ID” is used for identifying each record. The values from this column are unique and usually are generated automatically. The column “P_NAME” stores the product name while the column “P_SN” stores the product serial number.
- The second approach consists in inserting the product name in a table “PROD_2ND” and inserting the product serial number in another table “SN_2ND” (Fig. 5). The table “PROD_2ND” has two columns: “P_ID” and “P_NAME”. The record identifier is kept by the “P_ID” column and the product name by the “P_NAME” column. The second table “SN_2ND” has three columns: “S_ID”, “S_P_ID” and “S_SERIAL”. The column “S_ID” holds the record identifier, the column “S_SERIAL” holds the serial numbers and “S_P_ID” holds the product identification number from column “P_ID” from the product table “PROD_1ST”, meaning that there is a relation between table “PROD_2ND” and table “SN_2ND”.

If using the first approach (Fig. 4), then each record from the table will be one product. As it can be seen in table “PROD_1ST” there are 2 printers, 3 CPUs and 1 hard disk. If using the second approach (Fig. 5), instead of adding the product “CPU” three times the user will only add the three serial numbers in table “SN_2ND”. In a practical application, the product table “PROD_2ND” will have many columns for manufacturer name, product

PROD_1ST		
P ID	P NAME	P SN
1	Printer	56879
2	Printer	1236
3	CPU	9236
4	CPU	478
5	CPU	48993
6	Hard Disk	4139

Fig. 4. Relational database 1st approach.

PROD_2ND		
P ID	P NAME	
1	Printer	
2	CPU	
3	Hard Disk	

Relation

SN_2ND		
S ID	S P ID	S SERIAL
1	1	56879
2	1	1236
3	2	9236
4	2	478
5	2	48996
6	3	4139

Fig. 5. Relational database 2nd approach.

model, technical specifications, product image and others. By allowing the user to add only serial numbers to existing products, will reduce human error and improve production since the user will have to add only the serial number and not all the product details.

3. SYSTEM HARDWARE INFRASTRUCTURE

3.1. Client location

The sensors deployed in the location, are connected to a PC (data storing computer) by: custom hardware devices (computer acquisition boards), local area network LAN if the sensors have RJ45 (IP sensor), wireless area network WLAN, Bluetooth.

For security reasons the storing PC from the sensor location is not connected directly to the Internet, instead it access the Internet through a Router by VPN (Virtual Private Network).

The sensors, record the monitoring values in the internal memory and at specific time intervals (sample time) the data is send to the storing PC.

3.2. Service provider headquarters

The application server is connected to the internet by a router with firewall. The data received from acquisition computer from the location will be stored in a relational database.

The data will be available to the customers using web pages, displaying the data in several formats: tables, graphs, and downloadable files like pdf, text, and csv.

The service provider must ensure data security and privacy. Each customer must be able to see only the data provided by the sensors deployed in the locations that the customer owns.

3.3. Customer headquarters

Nowadays having access to Internet and a computer network is a need like the heating and electrical power installation. If the customer has Access Points in the computer network he can also browse the monitored data from tablet PCs and other mobile devices.

Since the client interface consists of web pages means that it is platform independent. In other words the customer will be able to access the data from Windows PC, Apple Mac, Linux, UNIX.

The client-server network infrastructure is described in Fig. 6:

- Other client computer – any other computer that has access to the internet in the remote location.
- Router – a device that transfers data between a computer network and a sub-network from one IP address class to another IP address class. Usually it makes the connection between the public network (Internet) and private network (home, enterprise). The common router has a RJ45 connector named WAN (wide area network) for the Internet cable and several other RJ45 connectors named LAN1, LAN2, LAN3, ... (local area network) for private network computers.
- VPN – virtual private network. It is a private network over a public network. It provides a secure channel between a local computer and another computer in a remote location. In this research, VPN provides a

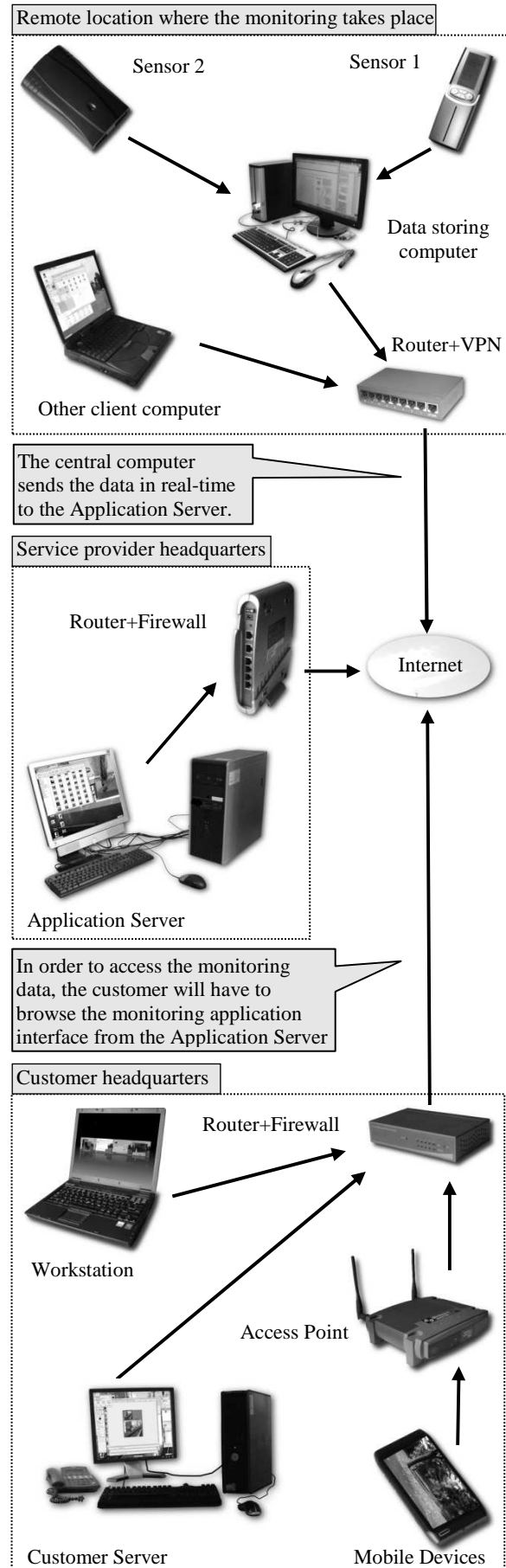


Fig. 6. Client-server network infrastructure.

secure connection between the Application Server and the Acquisition computer. VPN uses security features like encryption, authorization and tunnels.

- Workstation – a computer used for office work like CAD design, simulations, programming,
- Firewall – a barrier designed to prevent unauthorized or unwanted communications between computer networks [19].
- Customer Server – any type of server owned by the customer. Can be Web Server, Mail Server, File Server.
- Access Point – a device that allows wireless devices (smart phones, wireless computers or printers) to connect to a wired network. The access point has one RJ45 connector named LAN used for connection with a router. If the router has DHCP and DNS enabled, then the Access Point will allow the router to provide Internet connection for wireless devices. Also will allow file sharing between the computers in the wired network and wireless devices.
- DNS – Domain Name System. The DNS converts Internet domain and host names to IP addresses. It converts the site address typed in the browser address bar to the IP address of the web server hosting the site [20].
- DHCP – Dynamic Host Configuration Protocol. It allows a computer to join an IP-based network without having a pre-configured IP address.

4. SYSTEM SOFTWARE ARCHITECTURE

Description of the system software architecture in Fig. 7 [1 and 2]:

(1) The ORACLE XE database grabs the monitoring data from a file or database (Microsoft Access, Microsoft SQL, MySQL). For reading the data from the file it will use a PL/SQL procedure. The connection with other databases will be established by using ODBC (Open Database Connectivity).

(2) The data is transmitted in real-time to the ORACLE XE or ORACLE 11gR2 database on the Application Server.

(3) The user browses the web page from the Application Server.

(4) The web user interface developed with ORACLE APEX queries the database for the measured values.

(5) The web user interface generates reports and graphs.

(6) The end user views the results in his web browser.

4.1. Remote location data acquisition computer

Usually the manufacturers monitoring software stores the data on the acquisition PC hard drive into databases (Microsoft Access, Microsoft SQL, MySQL, FoxPro) or standalone files (*.txt). To be able to grab the monitoring records from the manufacturers database or standalone files and send it to the server, this research suggests the deployment of an ORACLE XE database on the acquisition computer. The ORACLE XE database can be installed on Windows or Linux and will allow to create programs with PL/SQL in order to read the files which

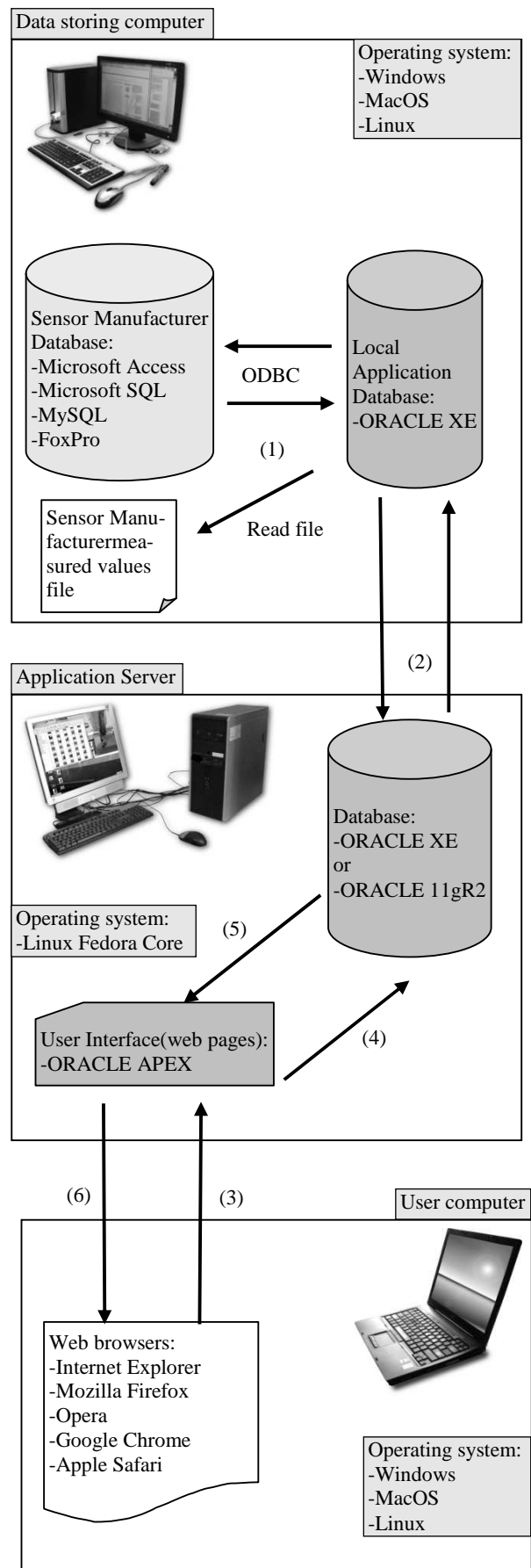


Fig. 7. System software architecture.

contain the monitoring records or accessing other databases through ODBC (Open Database Connectivity).

The PL/SQL procedures will collect the data from files or other databases and store it inside virtual tables in the XE database. Then another PL/SQL procedure will send the data to the server in real-time. In case of connection failure with the Application Server, the sensor data will remain inside the ORACLE XE database. When the connection is reestablished, all the data since the last working connection will be send to the Application Server.

4.2. The application server

In Fig. 8 it is explained how data is received and transmitted by the Application Server from the Service Provider Headquarters [4]:

(1) When a user wants to access the monitoring applications web page he/she will type the Internet address in the browser address bar. The request will be answered by a DNS server from the Internet which will point to the static IP address of the ADSL Router. The ADSL Router will transmit the request to the Firewall Computer which will forward (2) the request to the DMZ Computer.

(3) The DMZ Computer will ask the Data Base Computer (4) for the web page.

(5) The web page is sent by the Data Base Computer to the DMZ Computer.

(6) The DMZ Computer will forward the answer though the Firewall to the user computer.

From (7) to (11) it is explained the data flow inside the private network.

(7) The File Share Server connects to the Internet via Firewall Computer.

(8) User computers access data and the Internet by File Server DHCP and DNS.

(9) Backup date from the Database Computer (the ORACLE Database which contain data from sensors, the Monitoring Application).

(10) Backup date from the File Server.

(11) Backup data from user computer if necessary.

In order to view the measured data, the end user will have to access the monitoring application webpage from the application server. Credentials like username and password will ensure data privacy and grant access for each user only to monitoring records from the sensors that the user owns.

The security schema must allow the configuration of users, groups, and privileges for users. It must also allow password strength processing, meaning how many upper characters, lower characters, digits or special characters must the password have. It is able to feature a mechanism to announce the users to change password once a month.

The data must be displayed in reports that will allow the users to sort data by columns ascendant or descendant. The reports must feature filters in order to display only certain type of data. For example the user views a table with data from a thermometer that records temperature every two hours. This means 12 temperature values per day. The user must be able to filter the data to see only values between two dates, or to see only average values of temperature per day from one month. A search toolbar must exist to facilitate data search by keywords.

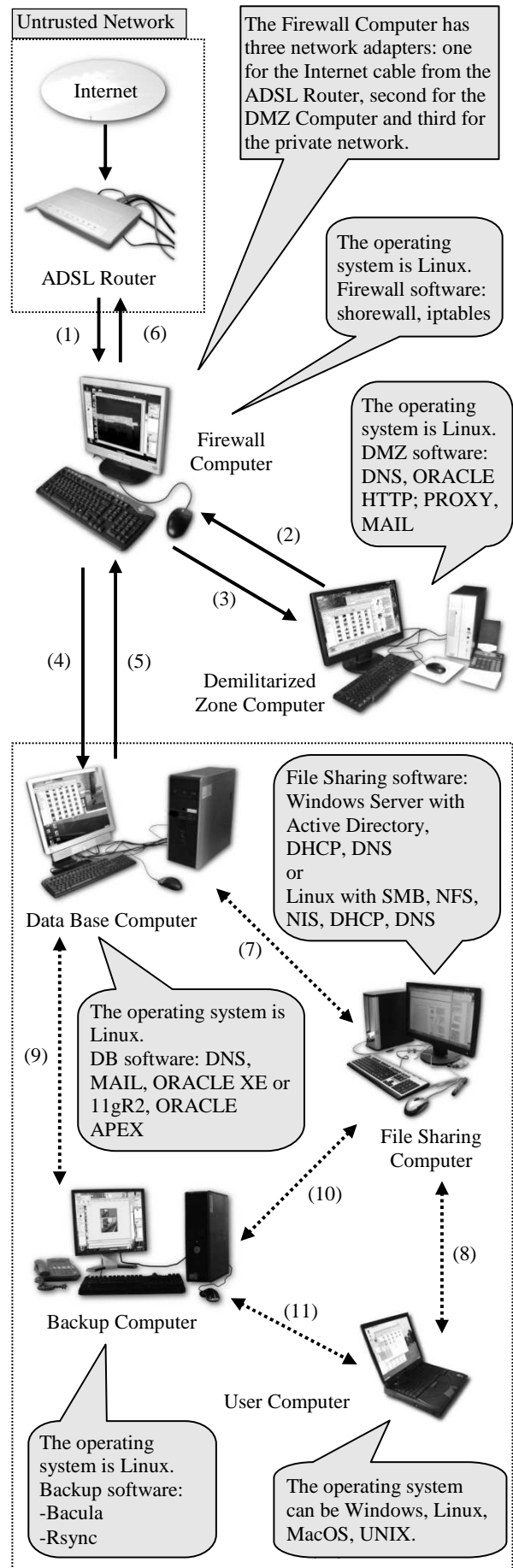


Fig. 8. Application server.

The graphs must also have filters and real-time update where it is necessary.

The web pages, the security schema (users, groups) and the data manipulation mechanism (reports, tables, graphs) will be developed in ORACLE APEX (Application Express).

The application developed in ORACLE APEX will access the data from the ORACLE XE or 11gR2 database and render reports and graphs.

In an industrial scenario for handling the data from a very large number of sensors, it is recommended the use of an ORACLE 11gR2 database. This 11gR2 is not free but it is designed to handle thousands of records and SQL interrogations with tremendous speed. Besides, if the service provider will have many customers, a licensed database will not seem so expensive.

Once a sensor is deployed and measuring environmental conditions, its position must not be modified unless it is done by approved personnel, other way the measuring data could be altered. For example if the sensor was initially hanged from the ceiling in the center of the room, it must not be placed in a corner of the room on a wall without the acknowledgment of the service provider because the temperature and the humidity it is not uniform in the room.

The Application Server is described in Fig. 8:

- ADSL Router – also known as DSL Modem is a device used to connect a computer or router to a telephone circuit that has Digital Subscriber Line (DSL) service configured [17].
- Firewall Computer – the first computer between the Internet and the organization's private network. It features three network adapters (Ethernet cards): one for Internet to plug the cable from the ADSL Router, second for DMZ, and third for the private network.
- Demilitarized Zone – DMZ is a physical or logical subnetwork that contains and exposes an organization's external services to a larger untrusted network, usually the Internet [18].
- Proxy – is an application or another computer that serves as an intermediate between clients and servers. Generally it is used to provide company employee Internet usage, to block undesired sites, to scan transmitted content for malware before delivery [16].
- Demilitarized Zone Computer – this computer host the DNS Server so users can access the monitoring application web pages by typing the Internet address in the browser address bar, and the ORACLE HTTP Server to make the monitoring application web pages available to user from the Internet.
- Data Base Computer – the computer where the monitoring application is deployed. It host the ORACLE XE or ORACLE 11gR2 database, the ORACLE APEX and the developed monitoring application.
- Backup Computer – the computer used in case of disaster and recovery of data (a computer that copies data from other computers at certain time intervals). A backup server that is able to make daily backups (full backup once a month, differential backup once a week and incremental backup every day). As an example of backup policy, full backup copies all data from the target computer on the first Monday of the

month. Differential backup copies every Monday except the first Monday because of the full backup only the data that has been added or modified since the last full backup. Incremental backup copies only the data that has been modified in that day during the rest of the week from Tuesday to Sunday. As a recovery procedure, first it must be restored the last full backup, then the last differential backup, and then all the incremental backups since the last differential backup. An open source software that can make full, differential and incremental backups is Bacula. The server side is deployed on a Linux machine and can make backups from both Windows and Linux computers.

- VNC – Virtual Network Computing is a graphically desktop sharing to remotely control computers.
- File Sharing Computer – the computer that share the organization's files with users. The software generally is Microsoft Windows Server with Active Directory to configure the private network to become a domain and not a workgroup. A domain network will allow the Network Administrator to change global settings (unlock user accounts, reset passwords) to several computers directly from the Server rather than going to each computer and change the settings. An open source alternative to Microsoft Windows Server is a Linux Server with Server Master Browser (SMB) configured as a Domain Controller for Windows Computers and Network File System (NFS) + Network Information System (NIS) which is a Domain Controller for Linux Computers. A VNC Server (Virtual Network Computing) will allow the users to work (create, edit documents) directly on the server from the office computers. By using VNC the data will be centralized on the File Server meaning that the users' computers do not have to be hardware overkill.

5. CONCLUSIONS

This paper describes a solution for automated centralization of environmental parameters data from sensors acquired from different manufacturers, deployed in locations with special environment requirements, into a software platform and centralizing the results in one user interface.

For collecting data from different types of sensors, made by different manufacturers this research suggests using an ORACLE XE free database, or for industrial use a licensed ORACLE 11gR2 database deployed on an open source operating system like Linux Fedora Core or CentOS. A web base application for data manipulation can be developed using free software, ORACLE APEX together with other third parties open source software.

Since the client user interface consists of web pages means that it is platform independent. In other words the customer will be able to access the data from Windows PC, Apple Mac, Linux, UNIX.

The use of open source and freeware software guarantees that the source code of the software platform can be improved, modified and adapted by other programmers beside the original developers. Also facilitates the development of other software applications that could use the monitoring data [12].

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